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JOURNAL OF DAIRY SCIENCE

OFFICIAL ORGAN OF THE
AMERICAN DAIRY SCIENCE ASSOCIATION

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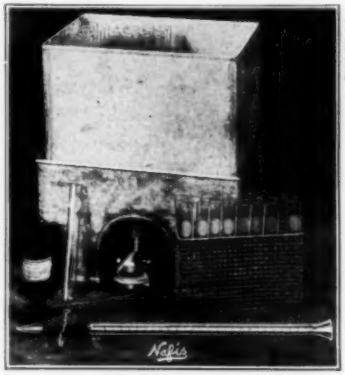

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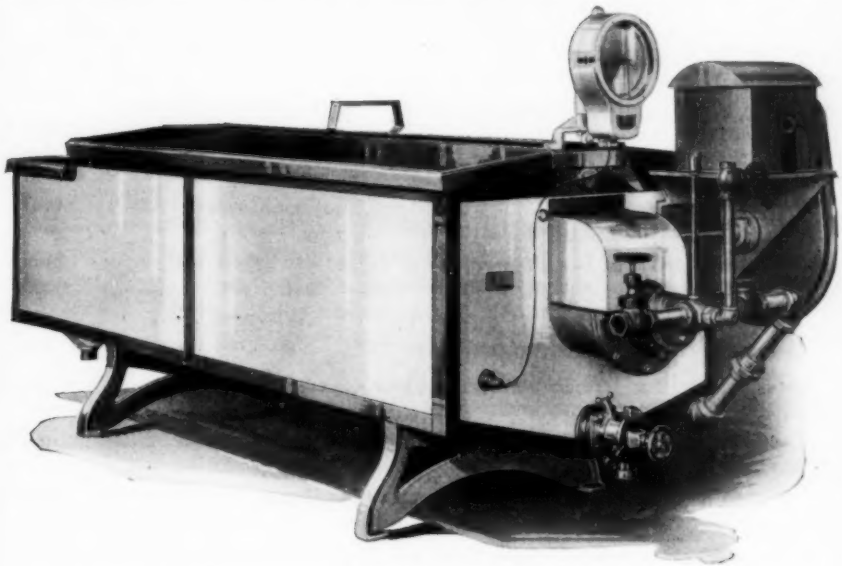

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THE RELATION OF SUNLIGHT TO THE GROWTH AND DEVELOPMENT OF CALVES*

T. W. GULLICKSON AND C. H. ECKLES

Division of Dairy Husbandry, University of Minnesota, St. Paul, Minnesota

In recent years the importance of sunlight to the health and well-being of the human infant has been fully established. Evidence has also accumulated which indicates that it bears a similar relation to at least some of the domestic animals. Thus it has been shown that poultry, especially baby chicks, are very susceptible to the absence of sunlight which apparently acts as a supplement to, or the equivalent of, the antirachitic factor of foodstuffs (1) (2). Swine also exhibit a need for it, (3) in fact gross symptoms as well as chemical analysis of blood and bone, together with histological examinations have indicated that sunlight is a factor of economic importance in the production of pork under confined conditions (4). In the case of the bovine, Hart and Steenbock (5) with mature milking cows obtained an increase in the amount of calcium retained by animals exposed to sunlight as compared with those kept in the dark, but this difference was less than had been expected. The greater susceptibility of the young growing animals of other species to a lack of sunlight, however, suggests the probability of a similar tendency in the young bovine. As yet no study has been reported of the relation of this factor to the development of calves. There is great need, however, for such information in connection with the correct interpretation of results from experiments in which calves are used and kept under confined conditions.

EXPERIMENTAL

According to the original plan, the experiment was to have terminated when the calves were six months old, the object of

* Published by permission of the Director as Paper 637, Journal Series, Minnesota Agricultural Experiment Station. Received for publication September 30, 1926.

the experiment being to observe the effect of a lack of sunlight upon the growth and well-being of young calves, but when at that age the results were all negative, it was decided to extend the period to include the time of first freshening or until the animals were about two years old. This made it possible to observe the effect of the absence of sunlight on the growth and well-being of the calves over a longer period and in addition also indicated, to a limited extent, its influence on reproduction.

Animals used and treatment

Four grade Holstein heifer calves designated by the numbers E-48, E-50, E-51 and E-52 respectively were used in the experiment. These animals were purchased in June, 1924, when from three to seven days old, and were from dams that had been kept under average farm conditions. Two of the calves, E-48 and E-50, known as the "no sunlight" group, were placed immediately on their arrival, in completely dark box stalls and thereafter during the period of the experiment were never exposed to direct sunlight. The stalls were of ample size to allow considerable exercising, and excellent ventilation was provided by means of a large electric fan. Occasionally, they were allowed to run free in the experimental yard out of doors during the dark part of the night. The other two calves, E-51 and E-52, known as the "sunlight group" were also kept in box stalls of the same size and shape as those provided for the others, but with no restrictions on the amount of light. During the first six months the practice was followed of placing them in pens of the same size out of doors in direct sunlight. After that, they were allowed to run freely with other experimental calves during the day time, being confined in their stalls in the barn at night. This did not decrease their exposure to sunlight, but no doubt increased the amount of exercise taken.

Ration fed

The ration, which was uniform for the four animals, was not selected as ideal for dairy calves, but because it is typical of that

fed on many dairy farms, and is also rather low in calcium which should make conditions favorable for positive results if sunlight is a factor in the utilization of this mineral by cattle. Whole milk was fed during the first three or four weeks, then replaced with skimmilk which was fed until the calves were about six months old. Timothy hay of fair to poor quality, fed ad libitum, constituted the only form of roughage. The grain fed consisted of a mixture of three parts by weight of cornmeal and one part each of corn gluten feed, wheat bran, and linseed oilmeal. During the first few months grain was fed ad libitum, but after that the amount provided was regulated so as to furnish the nutrients required according to the Morrison standard for growing dairy cattle. Shavings were used for bedding, so no nutrients were obtained from that source.

Weights of the animals were taken every ten days and measurements of height at withers were made every thirty days. Daily observations were made of the condition and behavior of all animals and any abnormality noted.

RESULTS

Throughout the entire period of approximately two years, all four animals continued normal in all outward respects. As is shown in figure 1, with few exceptions, all made gains equal to or better than normal during the entire period. It is worthy of note, however, that from the beginning almost invariably the two calves raised in the dark made better gains than did the check animals. This was, perhaps, to be expected if the lack of sunlight did not act as too great a disturbing factor, because these animals were more comfortable and received less exercise than the others that were turned out of doors. Table 1 shows that the ration was ample both as to protein and total digestible nutrients, usually supplying a slight excess of both over the amounts prescribed by the Morrison standard.

All the heifers came in heat the first time when less than a year old and the two check animals, E-51 and E-52 were bred and became pregnant at their first heat period due to the presence of

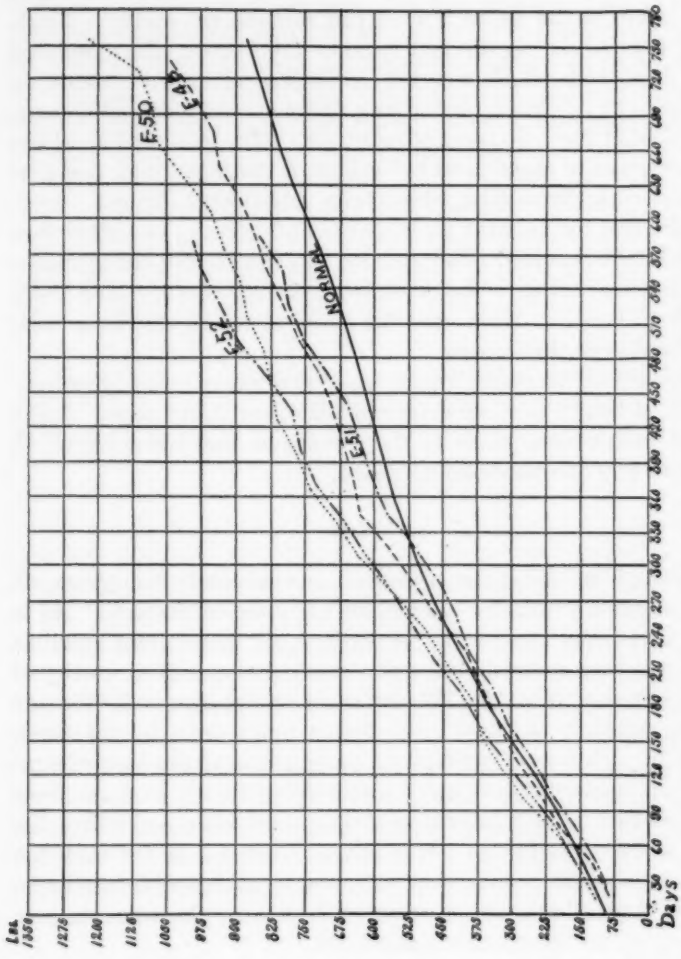

FIG. 1. GROWTH OF THE FOUR CALVES USED IN THE EXPERIMENT COMPARED WITH THE NORMAL CURVE
All received similar rations but E-48 and E-50 received no sunlight during the entire period.

TABLE 1

Showing daily rations fed and nutrients and minerals provided each calf at intervals of 120 days beginning at 30 days of age, also nutrients required by the animals at the different ages according to Morrison standard

NUMBER OF ANIMAL	GROUP	AGE	DAILY RATION		NUTRIENTS IN RATION		NUTRIENTS REQUIRED BY ANIMAL (MORRISON STANDARD)		MINERALS IN RATION	
			Timothy hay	Grain§	Crude protein	Total digestible nutrients	Crude protein	Total digestible nutrients	Calcium	Phosphorus
		days	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*grams*	*grams*
E-48	No sunlight	30*	0.5	0.5	0.43	2.42	0.33	1.97	5.23	4.88
		150†	2.0	4.5	1.32	5.67	0.73	4.93	12.25	18.21
		270	5.5	6.0	1.10	7.46	0.94	7.22	6.98	19.21
		390	10.0	6.0	1.14	9.55	1.14	8.90	10.63	21.97
		510	14.0	6.0	1.33	11.52	1.26	9.76	13.87	24.43
		630	14.0	6.0	1.28	11.76	1.36	10.50	13.87	24.43
		740	13.0	8.0	1.55	12.77	1.44	10.96	13.90	29.09
E-50	No sunlight	30*	0.5	0.5	0.43	2.42	0.40	2.48	5.23	4.88
		150‡	3.0	5.0	1.51	6.74	0.81	5.65	14.51	20.90
		270	6.0	7.0	1.27	8.49	1.00	7.79	7.80	22.15
		390	12.0	7.0	1.34	11.31	1.24	9.61	12.67	25.84
		510	14.0	7.0	1.49	12.28	1.33	10.33	14.29	27.07
		630	16.0	7.0	1.48	13.55	1.41	10.85	15.91	28.30
		750	17.0	9.0	1.81	15.59	1.56	11.38	17.56	34.19
E-51	Sunlight	30*	0.5	0.5	0.43	2.42	0.31	1.80	5.23	4.88
		150†	2.0	4.5	1.32	5.67	0.70	4.69	12.25	18.21
		270	5.5	6.0	1.10	7.46	0.89	6.62	6.98	19.21
		390	10.0	6.0	1.14	9.55	1.09	8.50	10.63	21.97
		510	16.0	6.0	1.39	12.50	1.25	9.68	15.49	25.66
		600	16.0	6.0	1.34	12.78	1.32	10.23	15.49	25.66
E-52	Sunlight	30*	0.5	0.5	0.43	2.42	0.39	2.39	5.23	4.88
		150‡	3.0	5.0	1.51	6.74	0.79	5.54	14.51	20.90
		270	6.0	7.0	1.27	8.49	1.02	7.95	7.80	22.15
		390	12.0	7.0	1.34	11.31	1.22	9.48	12.67	25.84
		510	14.0	7.0	1.49	12.28	1.34	10.38	14.29	27.07
		600	16.0	7.0	1.48	13.55	1.27	9.89	15.91	28.30

* Ration also included 10 pounds whole milk.

† Ration also included 14 pounds skimmilk.

‡ Ration also included 16 pounds skimmilk.

§ Grain mixture made up of: 300 cornmeal; 100 corn gluten feed; 100 wheat bran; 100 linseed oilmeal.

a young bull in the experimental lot. E-50, on the other hand, was not bred until she was about sixteen months old when one mating was sufficient for conception. E-48, the other no-sunlight heifer, was found after being on the experiment for about a year, to have malformed reproductive organs which made it impossible for her to reproduce, although oestrum was possible. This deformity, however, was declared as not being due to the treatment

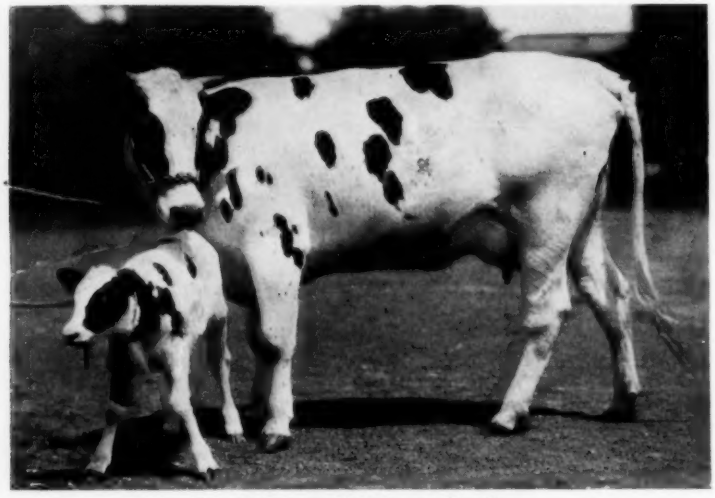

FIG. 2. HEIFER E-50 WITH HER CALF

The calf was dropped after the mother had been kept in the dark from the time she was one week old, a period of over two years. Both animals appear normal in all respects.

she had received. From table 2 it can be seen that the other three heifers carried their calf the full normal period. All the calves except that of E-52 were normal at birth and all the heifers passed the afterbirth within twenty-four hours after freshening. As indicated in table 2, E-52 of the sunlight group, dropped a rather small and slightly deformed calf, and although both its eyes were present it was entirely blind. It is possible that the ration fed was lacking in the fat soluble vitamin and thus contributed toward

this condition. This, however, does not seem probable as both of the other heifers dropped normal calves. It is also well-known that cows kept under normal conditions will sometimes drop deformed as well as blind calves.

The ration, as has already been mentioned, provided an adequate supply of protein and total digestible nutrients as based on the Morrison standard, but was, as is shown in table 1 exceedingly low in its calcium content; in fact, when considered on the dry matter basis it contained only about 0.2 per cent of calcium. The significance of this fact is apparent when, according to Meigs and his coworkers, it is considered that perhaps only about half of the total amount of calcium present in the ration

TABLE 2

NUMBER OF ANIMAL	GROUP	GESTATION PERIOD	SEX OF CALF	WEIGHT OF CALF	CONDITION OF CALF AT BIRTH
				pounds	
E-48	No sunlight	Deformed	Reproductive organs		
E-50	No sunlight	Normal	Male	89	Normal
E-51	Sunlight	Normal	Female	79	Normal
E-52	Sunlight	Normal	Female	60	Blind and slightly deformed

is assimilated. The supply of available calcium was sufficient, however, to enable all four heifers to make better than normal gains in both weight and height and to continue in all outward respects in normal well-being during the entire period of the experiment. The fact that no significant differences were noted between the two groups at any time appears to indicate that the lack of sunlight did not exert any considerable effect on calcium assimilation, otherwise it seems it would have become apparent during the two year period when the calcium supply was at such a low level.

Another matter worthy of notice in connection with the mineral content of the ration is the relative amounts of calcium and phosphorus present. As is shown in table 1, the total amount of

phosphorus almost invariably exceeded that of the calcium, and most of the time by nearly two to one. This represents a condition almost the opposite of the optimum as recommended by McCollum (6, 7) and according to his views (8) "the ratio between the concentration of calcium and of phosphorus in the diet may, within certain limits, be of greater significance to the welfare of an animal than the absolute amounts of these substances which the diet contains." The fact, however, that no ill effects were noted in any of the animals would indicate the condition was not a serious disturbing factor in either of the groups.

CONCLUSION

So far as could be measured by general observations, weights, and rate of skeletal growth, the absence of sunlight was without effect upon calves kept in darkness from the age of one week to two years. Normal reproduction also occurred.

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PERSISTENCY OF FAT SECRETION DURING THE LACTATION PERIOD AS AFFECTED BY AGE*

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In a previous paper (1) quantitative forms of expressing the persistency of milk and fat secretion during the lactation period were described. It was shown that when all conditions are held as uniform as is possible, the monthly milk or fat production during the lactation period after the maximum is passed, is a constant percentage of the preceding month's production. Pregnancy, seasonal changes (especially environmental temperature), the state of nutrition, and management of dairy cows may, however, cause slight changes in the rate of decline of milk and fat secretion.

In a study of the inheritance of the "persistency character" in the Guernsey breed, it was suggested that age might be an important factor influencing the persistency of milk and fat secretion. The only information found on the subject was the data presented by Sanders (2) of Cambridge, in a study of the lactation curve of English milk records. He determined the ratio of the total lactation yield to the maximum daily yield, which he called the *shape figure* (S.F.) of the cows' lactation. It was shown that the two-year-old animals had a higher S.F. than did the older animals. Since compiling and studying the data later to be presented, a paper by Gaines and Davidson (3) of Illinois, has appeared in which the statement is made that "the value of k tends to increase with age and yield; that is, the younger cows are more "persistent" than the older cows."

It appears evident that the age of the cow does influence her persistency of secretion. However, no theory is advanced in either paper to attempt to explain the results obtained. The object of this paper in addition to presenting data showing the

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relation between the persistency of fat secretion during the lactation period and age is to offer a possible explanation for the results.

In the study of persistency of secretion, it is necessary to have the itemized monthly records of production. The Advanced Register of Guernsey cattle is especially valuable as it contains a large number of such records and is the source of the data here presented. Only non-pregnant cows were included in this study as it has been shown that pregnancy affects the lactation curve when it extends more than four months during the lactation period. In order to make the results in each age group more nearly comparable, 100 records in each age group which were satisfactory in every respect were used. This was considered preferable to including a large number of records in the immature classes and only a limited number in the classes at advanced ages.

The influence of all other factors which might affect persistency have been neglected. It was hoped that the number of records would be sufficient to provide a random sample which would minimize the influence of these factors. The average monthly fat production from the second to twelfth months inclusive were determined by yearly age groups beginning at two years.

The results are presented in table 1. The average fat production from the second month to the twelfth month is given. The per cent of the previous month's fat production is calculated in order to determine the rate of decline or persistency of secretion during the laction period. The *average* per cent decline of the previous month's production is considered the best indication of persistency. It will be noted that the average persistency of fat secretion declines rapidly between two and three, years and then less rapidly as maturity is reached. It will be seen that above six years, the number of records available decreases very rapidly, so that the data is unreliable in giving an indication of the effect of age on persistency during the declining segment of the curves of milk secretion, i.e., after eight years. The data by age groups is plotted in figure 1, and a curve drawn through the points. There is some irregularity between the observed values and the

TABLE 1

The effect of age on the persistency of fat secretion

Age	2 to 3 years		3 to 4 years		4 to 5 years		5 to 6 years		6 to 7 years		7 to 8 years		8 to 9 years	
Number of records	100		100		100		100		100		71		34	
Month of lactation	Average fat	Per cent of previous month's fat production	Average fat	Per cent of previous month's fat production	Average fat	Per cent of previous month's fat production	Average fat	Per cent of previous month's fat production	Average fat	Per cent of previous month's fat production	Average fat	Per cent of previous month's fat production	Average fat	Per cent of previous month's fat production
	pounds		*pounds*		*pounds*		*pounds*		*pounds*		*pounds*		*pounds*	
Second	40.44		47.37		53.94		54.96		58.17		55.49		58.05	
Third	40.92	101.18	46.17	97.46	51.24	94.99	53.52	97.37	55.62	95.61	54.59	98.37	58.14	100.15
Fourth	40.11	98.02	44.13	95.58	50.01	97.59	51.69	96.58	51.45	92.50	51.18	93.75	56.82	97.72
Fifth	40.05	99.85	41.13	93.20	48.21	96.40	49.71	96.16	50.88	98.89	49.22	96.17	52.26	91.97
Sixth	39.18	97.82	40.83	99.27	47.13	97.75	47.70	95.95	48.45	95.22	47.70	96.91	52.05	99.59
Seventh	37.86	96.62	38.97	95.44	45.21	95.92	45.84	96.10	47.04	97.08	45.80	96.01	48.97	94.08
Eighth	37.50	99.04	37.44	96.07	42.78	94.62	43.92	95.81	44.13	93.81	43.80	95.63	45.52	92.95
Ninth	36.52	97.38	36.42	97.27	42.30	98.87	42.15	95.96	43.18	97.84	41.07	93.76	42.35	93.03
Tenth	35.42	96.98	35.22	96.70	40.44	95.60	40.08	95.08	40.12	92.91	39.38	95.88	42.44	100.21
Eleventh	34.46	97.28	33.45	94.97	38.71	95.72	38.07	94.98	38.52	96.01	36.71	93.21	39.97	94.18
Twelfth	33.39	96.89	32.76	97.93	37.84	97.75	36.03	94.64	36.42	94.54	35.49	96.67	36.79	92.04
Average	37.80	98.11	39.44	96.39	45.25	96.52	45.78	95.86	46.73	95.44	45.49	95.64	48.48	95.59

smoothed curve. This may be due to the lack of control over many of the factors involved. It appears, however, to be an exponential curve, a mirror image of the curves relating age to weight and yearly milk production.

It may be concluded from the above data, as well as that presented by Sanders, Gaines and Davidson, that there is a distinct decline in the persistency of secretion during the second

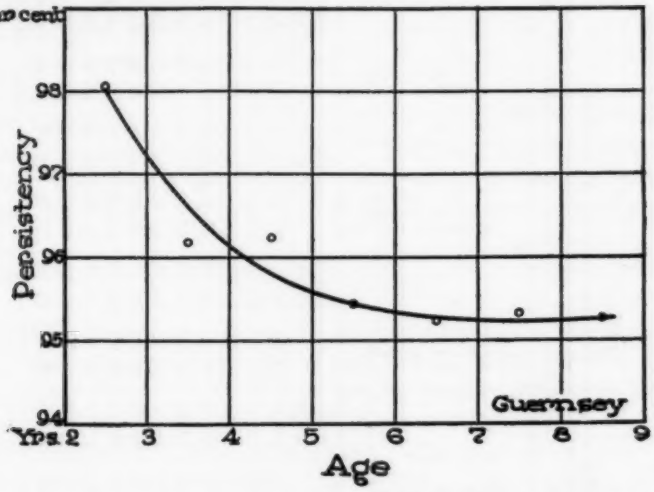

FIG. 1. The change in average persistency with age is indicated. There is a rapid decline which gradually slows up as maturity is reached. The points are the observed values with a smoothed curve of exponential form drawn through them. It will be noted that the curve is a mirror image of the curves relating age to weight and yearly milk production.

and third lactation periods, as compared with the first. As the two most important factors concerned in total yearly production are milk yield during the maximum month and persistency of secretion, and further, that yearly milk secretion increases with age, it is evident that the maximum month's secretion increases rapidly with age. In other words, while the so-called "persistency" character is declining with age up to maturity, the "maximum production" character is not only increasing with age, but

at a rate sufficient to overcome the influence of the former on total lactation yield. In advancing a theory to explain these results, it may be desirable to first indicate the source of the stimulation of milk secretion and its relation to the persistency or rate of decline.

THE STIMULATION OF MILK SECRETION

The similarity of the declining curve of milk secretion to the curve of decline of chemical reaction (of the first order type) has been pointed out (5). Milk secretion, even though a very complicated physio-chemical process, might follow a simple chemical law if governed by the slowest process involved. This limiting substance may be of the nature of a chemical catalyst or hormone, which is essential to the chemical transformations taking place in the active secretory tissue of the mammary gland. The consumption of this hormone at a rate in accordance with the exponential decline would furnish the regulating mechanism of milk secretion.

Evidence is gradually being accumulated which indicates the the source of this hormone or at least a hormone which causes active growth and proliferation of secretory cells of the mammary gland, and which eventually initiates a limited amount of secretion. Meyer (6) in a study of albino rats, found that as the time of puberty approaches, the milk ducts begin to proliferate and grow very rapidly, resulting in a dense arborization of ducts. It was observed that these changes in the milk ducts correspond with marked changes in the ovaries and showed large Graafian follicles in the process of development.

Changes in the non-pregnant guinea pig, studied by Loeb and Hesselberg (7), indicate that there is a cyclic change in the mammary gland which corresponds to the cycle in the ovary and uterus. Activity of the gland is at a maximum at the time of heat and ovulation, and gradually falls. At this time, cells in mitotic division are present.

In cattle, Hammond (8) states that after the first heat period the udder enlarges and the ducts grow in length, but it still con-

tains a large proportion of fat. He found that the growth of the milk ducts was due to the functioning of the ovaries and to the formation of corpora lutea.

It appears from the foregoing discussion that puberty and the accompanying changes in the ovaries at that time are responsible for the stimulation of the growth and proliferation of the mammary gland and the stimulation of a very limited secretion.

If pregnancy does not occur with the first ovulation the mammary glands undergo slight retrogressive changes; however, as the next ovulation approaches the mammary gland takes on a new development. Similar changes can be observed in some animals with each succeeding ovulation until pregnancy occurs.

The changes in the mammary gland during pregnancy have been studied in the rabbit by Lane-Claypon and Starling (9) and in the guinea pig, by Loeb and Hesselberg (10). Rapid proliferation of secretory tissue took place during pregnancy after nine days in the rabbit and twenty-four days in the guinea pig. A secretion could be pressed out of the gland during the latter part of the period of gestation.

In cattle, Asdell (11) reports that the amount of liquid that may be milked from the pregnant heifer increases very rapidly and abruptly when the animal is about half way through pregnancy. When a pregnant heifer was milked regularly during her first pregnancy, the yield of milk increased rapidly from the mid period until at calving time as much as 5000 cc. were being produced.

Thus it may be concluded that growth and proliferation of the secretory cells of the mammary gland takes place soon after pregnancy occurs. Coincident with it, or following the growth phase, the secretory phase of activity of the gland is begun. Considerable secretion occurs long before the end of pregnancy.

Asdell concludes that "there seems to be no necessity to postulate the production of an inhibitory hormone from the fetus which defers lactation until the fetus, and consequently the inhibition, is withdrawn by parturition. Such is not in accordance with the facts given in this paper, and indeed appears unnecessary, for while a cell is growing and dividing, surely it

cannot secrete. The only inhibition is that produced by the excitement of the cell to grow."

The source of the hormone causing the secretion of milk is much debated. The fetal hormone theory was one of the first proposed. Later the placenta and corpus luteum was suggested as the internal gland of secretion of this hormone. As all of these structures are associated with pregnancy, it is difficult to determine which is responsible.

While experimental data are not available, it is quite possible that the follicular hormone from the ovary isolated by Allen (12) may be responsible not only for the stimulation of the mammary gland to proliferation and secretion from puberty to the first pregnancy, but also during pregnancy. A relatively large amount of active material has been recovered from the placenta which by all tests is similar to the follicular hormone. Allen, Pratt, and Doisy (13) make the following comment on the endocrine function of the placenta:

> It is probably too early to draw general conclusions concerning the endocrine function of the placenta. It is rather difficult, however, to see how such large quantities of active substance could be retained in such a vascular organ as the placenta without passing freely into the maternal circulation. Since it is so well established that the development of the follicles is seriously inhibited during pregnancy, it would seem to us more probable that the human placenta takes over from the ovaries the major part of the function of the secretion of this hormone, thus maintaining the maximum function of the genital tract and initiating growth in the mammary glands during gestation.

If the placenta is the source of the hormone stimulating milk secretion during the gestation period, the source of supply would be cut off at parturition. This being the case, the rate of decline of milk secretion would necessarily be confined to the activity of the secretory cells either individually or collectively, and not to a diminution of the hormone at its source.

To account for the reduced rate of decline during the growth period, i.e., up to seven or eight years, it may be postulated that further development of the mammary gland up to its full mature

development may be brought about in any or all of the following ways: (*a*) The reoccurrence of the oestrus cycle, (*b*) another pregnancy, (*c*) a larger blood supply to the mammary gland accompanying growth in weight, (*d*) the increasing activation and perfection of functioning of the secretory cells with use.

GROWTH OF THE MAMMARY GLAND

The first two factors which may cause the rate of decline of milk secretion to be retarded would result from the growth of secretory tissue during the lactation period. With more cells beginning to secrete milk, the yield would be augmented to supplement the natural decline. As the data under consideration consisted of lactations of non-pregnant cows, only the first of these two factors could influence the rate of decline of secretion during the growing period of the cows under consideration. It is not unreasonable to assume that the oestrus cycles which reoccur soon after parturition cause further growth of secretory tissue during the lactation period. It is quite evident that the udder increases in size up to maturity and most rapidly during the second and third year. This growth is due to a stimulus other than that associated with body growth as it takes place only when the ovaries function. Little or no mammary development takes place in spayed heifers.

During the first pregnancy, growth of the mammary gland is very rapid. It is undoubtedly stimulated to further growth during the second pregnancy, but due to other factors accompanying pregnancy any stimulating effect would be masked. There is a difference of opinion as to the cause of the diminution of milk secretion during the latter part of pregnancy. Gaines and Davidson (3) have recently presented the side of those who believe that a hormone of pregnancy inhibits milk secretion and causes the decline observed in the data compiled at this Station (14), and by Eckles (15). Ragsdale, Turner and Brody (14) are of the opinion that the decline in milk flow during gestation is in part at least due to the demands of the growing fetus. The recent data by Asdell (11) strongly supports the conclusion that no

inhibitory hormone need be postulated to account for the decline of milk secretion.

Using questionable methods of calculating data on the weight of the fetus, Gaines and Davidson (3) compare the weight of the fetus and the rate of decline of milk yield due to pregnancy. The two curves were not found parallel, and therefore they conclude that "it seems unlikely that the rate of milk secretion is affected at all proportionately to the nutrients required by the fetus." Their assumption that the requirements of the fetus at any moment are proportional to its weight would not necessarily be true as it is well known that growth or milk secretion may be limited by a single deficiency. It might well be that milk secretion would be limited by the needs of the fetus for calcium and phosphorus for the development of the skeleton during the latter part of intra-uterine growth which may bear little relation to its change in weight.

The point which it is our desire to emphasize is that pregnancy unquestionably furnishes the "follicular" hormone that causes further growth and development of the mammary gland during the second and succeeding pregnancies up to the time of maturity. This development, however, is masked by the needs of the fetus which over-balance the increased secretion produced, due to the functioning of the new cells present.

ACTIVITY OF THE MAMMARY GLAND

The other factors which may influence the rate of decline or the "persistency" of milk secretion as the animal reaches maturity, would rest with the activity of the secretory cells present. If this would change for any reason, the persistency would follow a similar but inverse course. A close relation has been found between weight and yearly fat production as the dairy cow reaches maturity (4). There is a quite similar increase in weight and fat production up to seven or eight years in the Jersey cow. For each 100 pounds increase in live weight above 472 pounds, there is a corresponding 100-pound increase in yearly fat production. Within a single age class, however, there appeared to be

an increase of approximately 20 pounds of fat for each 100-pound increase in live weight. This was taken to indicate that the change in fat production with age is probably due to two separate factors; an increase in body weight contributing about 20 per cent to the total increased fat yield, while 80 per cent of increased fat yield is due to other factors accompanying increased maturity.

During the first lactation period of a heifer and to a lesser extent with older growing animals, the increase in weight and corresponding increase in the volume of blood will supply the mammary gland with a larger amount of blood. This increased blood supply is thought to be in part responsible for retarding or masking the natural (hereditary) rate of decline of secretion.

With the removal of milk either before or after parturition, the cells must gradually become adjusted to the changed conditions. The increasing activation and perfection of the functioning of the secretory cells to secrete milk up to their full capacity may also change with maturity of the animal. This change would also retard the natural decline in the rate of secretion.

SUMMARY

1. Using a method previously described for the quantitative determination of persistency of milk and fat secretion, a study was made of the effect of age upon this character.

2. Data were presented indicating that there is a decline in the persistency of secretion during the lactation period as the dairy cow reaches maturity.

3. A summary is made of the literature indicating the nature of the stimulation of mammary growth and secretion and the relation to the problem of the influence of age was indicated.

4. The theory is advanced that the normal or hereditary rate of decline of milk secretion during the early lactation periods is retarded due to further division of cells which become functional through the stimulation of the "follicular" hormone, and to the increased activity of the cells due to an increased blood supply and the perfection of the functioning of the cells.

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A NEW METHOD OF MANUFACTURING CREAM CHEESE OF THE NEUFCHATEL TYPE*

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Cream cheese is a soft, fresh cheese with a rich, mild acid flavor; a smooth, buttery texture; and a high percentage of milk fat. Strictly speaking, cheddar or American cheese, which is a hard-ripened cheese made from milk, should not be called cream cheese, even though it is often referred to as cream cheese and some state laws recognize it as full cream cheese when it is made from normal milk. Cream cheese is normally made by the neufchatel process from cream or from milk to which cream has been added.

The extent of the manufacture of cream cheese has increased greatly in recent years. Cream and neufchatel cheese constitute one of the leading varieties of cheese manufactured in New York State. The last available statistics for New York State[1] show that in 1924 there was sold to dairy plants for manufacture into cheese the following number of pounds of milk:

KIND OF CHEESE	POUNDS OF MILK
American or cheddar	43,500,000
Cottage, pot and bakers	19,700,000
Cream and neufchatel	9,900,000
Limburger	4,200,000
All other kinds	7,900,000

The percentage of fat in cream cheese varies from 38.6 to 48.0, according to Matheson, Thom, and Currie.[2] The same authors give the moisture content as varying from 30 to 48 per cent.

* Received for publication December 3, 1926.

[1] Statistics relative to the dairy industry in New York State, 1924, Bul. 180, Department of Farms and Markets, 1925.

[2] Matheson, K. J., Thom, Charles, and Currie, J. N. Cheeses of the neufchatel group. Conn. Agr. Exp. Sta. (Storrs), Bul. 78, 1914.

The richness of cream cheese should be evident in the characteristics of the cheese when compared with neufchatel or cottage cheese. Cream cheese should have a mild acid, distinctly creamy flavor. The acid and salt content should be lower than in cottage cheese. The texture is usually described as very smooth and buttery. It should spread almost as freely as butter. The body should be more rigid than cottage cheese so that cream cheese can be sold in boxes and packages. It should not be crumbly or too sticky and should pack very solidly. These properties make it possible to cut cream cheese loaves into slices which do not break and which have a solid surface.

The retail price of cream cheese is usually higher than the price of butter and several times greater than the price of cottage cheese. The consumer buys it in small quantities, one-half pound or less and appears to consider it a delicacy. While much of this cheese is consumed as any ordinary cheese would be, it is especially well considered as a spread for crackers in place of butter, as a filling for sandwiches, and in salads. This cheese is often mixed with ground pimento, nuts, olives, mixed sweet pickles, and salad dressings to give variety, especially when used in sandwiches.

THE NEUFCHATEL PROCESS

Investigations upon the manufacture of cream cheese are somewhat limited in number, although the methods of manufacture often appear in the literature. Matheson, Thom, and Currie give the details of the process and stress certain points of special importance. The milk must be low in acid and of excellent quality. A low quantity of good starter and rennet should set the milk at 70° to 75°F. in twelve to eighteen hours. The curd should be drained in sacks at a temperature of 50°F. and in a humid atmosphere. Pressure is essential to expel the last traces of free whey. The finished cream cheese should contain 38 to 43 per cent water, 43 to 48 per cent fat, and 0.5 to 1.25 per cent of salt.

Marquardt[3] improved the process in several respects. Pas-

[3] The investigations by J. C. Marquardt, New York Agricultural Experiment Station, have not yet been published.

teurization and commercial starters improved the flavor and keeping qualities of the cheese. Homogenization of the milk to which cream had been added reduced the fat lost in the whey and permitted the use of richer cream without excessive fat losses.

Certain difficulties in the present manufacturing process are occasionally encountered in commercial practice. Lack of a proper control of temperature conditions during setting and draining, combined with variations in rennet action and acid development, may result in a somewhat granular, crumbly cream cheese. Draining of the whey from the curd in the bags is usually slow and the acid development may result in a sour or yeasty cheese. Proper drainage of sufficient amounts of whey may take too long a time so that the manufacturer may pack the cheese too wet. A cheese with a high moisture content keeps poorly.

PLANS OF THIS INVESTIGATION

The results of studies of homogenization and the fat clumping in milk and cream at this station made it reasonable to suppose that through homogenization of cream its viscosity or plasticity might be increased to such an extent that a body and texture suitable for cream cheese would be produced. Consequently, cream was standardized to compare in composition with cream cheese. The cream was pasteurized and homogenized. The result of the first trial was encouraging enough to warrant a rather detailed study of the method, especially considering the evident advantages of the method if it proved successful. The method is also of scientific interest and might serve as a basis for other investigations of similar character. Consideration was given to the effect of varying percentages of fat and total solids, of varying temperatures and pressures of homogenization, etc.

Unless otherwise stated in the manuscript the Manton-Gaulin homogenizer, Type 60, with the single stage valve, was used in the manufacture of the cream cheese.

THE METHOD

The new method can be presented to best advantage by giving, first, the final method in detail as adopted, and later, by giving the effect of variations from the standard method.

Sweet cream of good flavor containing 40 to 45 per cent of fat was the basis for the cheese. To this cream 5 per cent of soluble dry skimmilk of good flavor was added. Either 1 per cent of high grade powdered pure food gelatin or 0.5 per cent of powdered agar free from objectionable flavor and odor was stirred into the cold cream.

This mixture was then pasteurized at 145°F. for thirty minutes if gelatin was used, and at 180° to 185°F. for ten minutes if agar was used. After pasteurization the mixture was cooled to 110°F. Common salt to the extent of 0.75 per cent, and 0.5 to 1.0 per cent of good commercial starter were then added. The mixture was passed through a coarse strainer into the homogenizer. The homogenization pressure of 3500 to 4000 pounds per square inch gave best results. The cream as it left the homogenizer had the consistency of soft butter or was slightly stiffer than ice cream as it comes from the freezer. The warm cream mixture was usually raised 5 to 10 degrees in temperature during the homogenization process.

The cream mixture was immediately placed in the final container and allowed to stand in a refrigerator at 32° to 40°F. for one or two hours until the temperature of the cheese was reduced to 70°F. The cheese was held at 70°F. for ten to fifteen hours or until it had developed sufficient acid to have a mild acid flavor. The product was then considered to be cream cheese. It was stored at 32° to 40°F. and was ready for immediate consumption. At this temperature cheese was held for two to five weeks without undergoing any serious deterioration in flavor.

Cream cheese made by this process was always smooth and buttery in texture without any traces of crumbliness. Its body was firm. The cheese possessed excellent spreading qualities and could be sliced as well or better than cream cheese made by the old process. It looked and tasted richer then the ordinary cream cheese, even though it did not contain a higher percentage of fat.

INFLUENCE OF VARYING PERCENTAGES OF FAT

Experimental cream cheese were prepared containing 30, 35, 40, 45, and 50 per cent of milk fat. Increased percentages of fat

caused increased firmness of body and decreased the quantity of whey that would drain from the cheese under adverse conditions.

Cheese containing 30 per cent fat was quite unsatisfactory, due to its soft sticky condition and leakage of whey when warmed to 70°F. or above. Under ideal conditions 35 per cent of fat was satisfactory, but this quantity of fat would not be sufficient for commercial conditions. The most satisfactory cheese was made with 40 to 42 per cent of fat and unquestionably the flavor was finest with this richness. When this cheese was stored above 70°F. some whey drained from it. Although this small amount of whey drainage is objectionable, it must not be forgotten that cream cheese is perishable and should always be kept in a cold place. If the cheese is stored above 70°F., it will spoil quickly irrespective of whey drainage. The body of the cheese with 40 per cent of fat was sufficiently firm and free from stickiness to permit the proper slicing of cheese loaves. The flavor was rich, creamy, and mildly acid. The texture was very smooth, buttery, free from crumbliness, and the cheese spread easily.

When the percentage of fat was increased to 45 per cent two slight alterations in the cheese were made. The flavor was somewhat richer and a few people who ate the cheese plain without other foods said that it was a little too rich. Cheese with this percentage of fat did not leak whey at any temperature up to 85°F. When 50 per cent of fat was used the cheese was noticeably too rich in flavor for many people who ate it.

A limited number of fat globule measurements were made to show the effect of homogenizing the cream mixture upon the size and distribution of the fat globules. One cubic centimeter of cream was diluted with 99 cc. of distilled water and examined in hanging drop preparations. The fat globules in the cream after pasteurization and prior to homogenization were 4.2 microns in diameter, and in 100 fields examined all existed as individuals. After homogenization the size of individual fat gobules was determined from those existing singly because of the difficulty of measuring globules present in clusters. The size of the clusters or aggregates of fat globules and the ratio of individuals to cluster were determined. A total of 128 fat globules had

an average diameter of 2.04 microns. In the same microscopic fields there existed 219 clusters with an average size of 11.9 by 8.2 microns. It was evident that most of the fat globules in the homogenized cream existed in large clusters of globules about one-half their original size.

The aggregation of the fat globules formed a network in which the milk serum was held. The body and texture of the cheese was probably due to this changed condition of the fat, a change which might be considered in colloidal chemistry as a change of the fat from the dispersed to the continuous phase.

INFLUENCE OF VARYING PERCENTAGES OF MILK SOLIDS NOT FAT

An attempt was made early in this work to make a firmer cheese which would not leak whey by increasing the percentage of milk solids not fat through the use of dry skimmilk. Increased percentages of milk solids not fat reduced the rich fat flavor to a considerable degree and improved the body by making it slightly firmer and less sticky. It did not have any marked effect upon whey drainage which was so greatly altered by the percentage of fat.

The percentage of milk solids not fat was held low for two reasons. If 10 per cent or more of dry skimmilk was used, the finished cheese could develop too high a percentage of acid at too warm storage temperatures. Furthermore, when exposed to drying conditions the milk sugar crystallized out and formed a grainy coating on the cheese. The addition of 5 per cent of skimmilk solids is desirable to decrease the buttery taste of the cheese, to increase slightly the firmness of the cheese, and to give the cheese better slicing properties. It probably would have been desirable to have omitted the additional milk sugar, but no feasible method was apparent by which the skimmilk solids could be obtained without the sugar.

INFLUENCE OF VARYING CONDITIONS OF HOMOGENIZATION

Greater homogenization pressures were essential in the production of cream cheese by the new method than are commonly employed in the manufacture of other dairy products. As a

general proposition it was found that pressures varying from 3500 to 4000 pounds per square inch produced a firmer bodied cheese with less stickiness and less drainage of whey than did lower pressures. When the fat content was high, 45 to 50 per cent, 500 pounds less pressure was sufficient and 4000 pounds pressure produced a cheese which was somewhat too rich in taste and resembled, to some extent, cream almost ready to form butter in the churn.

Any temperature of the cream above 105°F. was suitable for homogenization so far as the body and texture of the resulting cheese were concerned, but it is obvious that starter could not be safely added to cream homogenized at a temperature much in excess of 110°F. because the temperature was increased 5° to 10°F. by homogenization. In several tests the cream was homogenized at 145°F., cooled to 70°F., and starter added. The salt was sometimes added with the starter and also after the cheese had ripened to the proper degree. No special advantage could be determined in this method of adding salt and starter after homogenization, and it had the disadvantages of making extra work and the excessive mixing of the cheese tended to make it sticky.

Cream cheese was also prepared from cream which had been pasteurized, cooled, and ripened with commercial starter at 70°F. The cream was then pasteurized again, salt was added, and the whole mixture with the proper percentage of acid was homogenized. By this method it was hoped that the acid development would be checked even when the finished cheese was stored at too warm a temperature. The method proved unsatisfactory because the homogenization of sour cream produced a cheese with a soft sticky body from which whey drained freely.

Commercial rennet was tried by adding it when the starter was added in the recommended process. The rennet gave the homogenized product a more buttery appearance and taste, and whey drained much more freely from the cheese. When added after homogenization the rennet caused increased drainage of whey. For these reasons the use of rennet in the manufacture of this cheese was not desirable.

The cream was homogenized at colder temperatures with poor

results. The fat was not properly homogenized, the cream appeared to be partially churned, and the body of the cheese was softer than usual. Whey drained from the cheese quite freely. Measurements of 100 fat globules in cream homogenized at 90°F. showed them to be 3.5 microns in diameter or only slightly smaller than those in normal cream. Only 46 clumps measuring 11.6 by 9.7 microns were found per 100 individual fat globules, showing a great reduction in the aggregation of the fat globules.

RIPENING THE CHEESE

The quantity of starter required to develop the proper acidity was dependent upon many conditions, but 0.5 to 1.0 per cent usually proved successful.

The percentage of salt added to the cheese had an effect not only upon the rate of acid development, but also upon the kind of flavor produced. When the percentage of salt was held below 1.0, the salt did not seriously interfere with the growth of the starter organisms.

Most starters are past the period of maximum activity when added to dairy products for ripening purposes, so that a period of lag was always encountered. In cream cheese, due to the added effect of heating the starter from 110° to 120°F., considerable time elapsed before acid development commenced. For these reasons speed in cooling the homogenized cream was not very essential. In cold weather good results were secured by placing the warm cheese as it came from the homogenizer in the room for ripening at 70°F. without previous cooling. In the summer this procedure could not be followed because the cheese became sour without developing desirable flavors. For this reason it was deemed advisable always to cool the cheese to 70°F. by placing it in a refrigerator previous to ripening.

THE USE OF AGAR AND GELATIN IN CREAM CHEESE

Agar and gelatin were tried in the cream cheese for the purpose of holding the whey so that none would drain out even though the cheese were stored too warm. The quantity of agar was

varied from 0.2 to 1.0 per cent and the quantity of gelatin from 0.5 to 2.0 per cent. Both the agar and gelatin were dissolved in hot water and stirred into the cream, and they were dissolved by mixing the dry powders directly into the cream.

The water required to dissolve the agar or gelatin was a distinct disadvantage because it increased the percentage of water in the cheese. Hence, after several trials, this method was discontinued and the dry gelatin or agar was added directly to the cream and dissolved by pasteurization. The gelatin presented no problem in this respect because it dissolved readily at the ordinary pasteurization temperature of 145°F. Tests[4] were made to determine the temperature and time required to dissolve powdered agar in water. It was learned that powdered agar began to dissolve at approximately 170°F. and a temperature of 180°F. for ten minutes seemed to dissolve the agar as well as did the boiling temperature. For this reason the powdered agar was dissolved in the cream by pasteurization at 180° to 185°F. for ten minutes.

Several tests with varying percentages of gelatin and agar showed that 1.0 per cent of gelatin or 0.5 per cent of agar gave best results. Since the cream cheese contained 50 per cent or less of water, the actual concentration of gelatin in water was 2.0 per cent and of agar 1.0 per cent. Both of these percentages were sufficient to form a jelly at room temperature. The presence of these gelatinizing substances produced a cheese with improved slicing qualities and a slightly firmer body. They also reduced the tendency of cream cheese to exude whey at warm temperatures, but neither weak agar nor gelatin jellies in the cream cheese could hold the whey so that some of it would not drain out of the cheese if the cheese were improperly made in other respects. The presence of agar or gelatin in the cheese was distinctly advantageous.

The powdered agar used for cream cheese making was of excellent quality and practically free from flavor and odor. Powdered pure food gelatin of high quality, such as that used in ice cream, proved to be an excellent grade for this purpose. The use of

[4] These tests were made by J. C. Marquardt of this Station.

agar had the disadvantage of requiring a high temperature to dissolve it, and its use had the advantage of making a firmer bodied cheese of improved slicing qualities. The use of agar is especially recommended.

ADVANTAGES AND DISADVANTAGES OF THE NEW METHOD

The new method of manufacturing cream cheese had several distinct advantages over the old neufchatel process.

When the milk for cheese making was received it was immediately reduced to the same approximate bulk as the finished cheese by separating into rich cream. This reduced the volume of cream which needed to be handled. No bags for drainage were needed. The acid development could be checked at any time by cooling the cheese because the moisture content was standardized before the cheese was made. This permitted better control of the extent of acid development and prevented spoilage of cheese by too much acid in a slow draining curd.

The cream cheese could be made more uniform in body and texture by the new process. The body and texture were determined largely by the composition of the cheese, the sweetness of the cream, and homogenization temperatures and pressures. These factors were readily controlled and uniform cheese was made. The labor needed to make cream cheese by the new process was considerably reduced.

Cream cheese of more desirable characteristics was made by the new process. It was smoother and more buttery, tasted richer, spread better, and sliced as well or better than cheese made by the neufchatel method. Its flavor from the standpoint of acid development and bacterial growth could be controlled to better advantage and the cheese was finished and in the refrigerator twelve to twenty-four hours sooner when made by the new method. The cheese could be packed more solidly in loaves or packages, and probably because of the exclusion of air, it did not mold as readily under improper storage conditions. The cheese was never crumbly.

It seldom occurs that a new method is proposed which in all respects is advantageous to use. Cheese made by the new method

had too high a milk sugar content which permitted the excessive development of acid under warm storage conditions. This disadvantage was offset to some extent by a reduced mold growth. Cheese made by the new method was considered too rich and buttery tasting to suit a few people, but it should be stated that this cheese was consumed in rather large quantities before this characteristic was discovered. It was essential that rich tasting cheese be made by this process, because a low percentage of fat was inducive to leakage of whey. Cheese of a given percentage of fat tasted richer when made by the new process.

The cheese made by the new process was more pasty than regular cream cheese. However, it sliced just as well as any neufchatel cream cheese made experimentally or purchased in the local market. All cream cheese is too sticky to cut with a knife. It should be sliced with a wire or string after the tin foil surrounding the cheese has been cut with a knife.

MILK YIELD IN RELATION TO RECURRENCE OF CONCEPTION*

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INTRODUCTION

Lactation is known to affect the reproductive cycle in man and some of the lower animals. Hammond (1) has shown experimentally in the rabbit that when lactation proceeds at a high level pregnancy is apparently inhibited. It seems to be a prevalent opinion that the fitting and management of cows on official test to secure as high a level of milk production as possible has a tendency to interfere with the occurrence of conception. The relation of the rate of milk secretion to the recurrence of pregnancy is not only of physiological interest, but in the case of the cow it becomes also of much economic interest.

It is well known that the economy of milk production in the cow is very closely related to the amount of milk produced, expressed as an average per year over the life of the cow. The factors contributing to the average yield per year include three major physiological elements: (*a*) frequency of calving; (*b*) initial or maximum rate of milk yield following calving; (*c*) persistency of lactation or the rate of decrease in the rate of yield with advance in lactation. These three elements may be regarded as given in order of their importance, inasmuch as the bearing of young is ordinarily essential to the initiation of milk secretion, and inasmuch as initial rate of yield is a much more powerful factor determining yearly yield than is persistency of lactation.

The common practice of dairymen is to breed their cows to freshen about once a year and this practice is essential to efficient milk production regardless of the value of the calf itself. Frequent calving is necessary to renew the stimulus to milk secretion and essential to maintain the mammary gland at the highest

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average rate of secretory activity. This may be demonstrated from theoretical premises. It is well known that the average lactation curve is of a descending exponential type [cf. (2), (3), (4)] terminated more or less abruptly by advanced pregnancy through natural and artificial agencies [cf. (5), fig. 9]. The theory of the case is set out in figure 1.

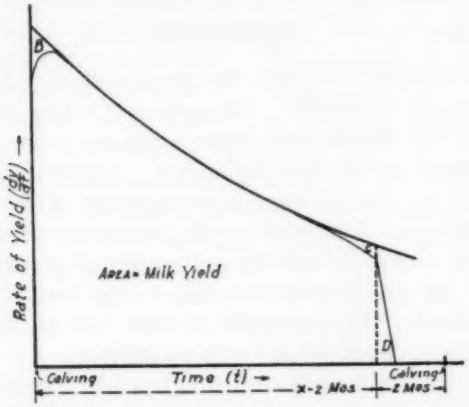

FIG. 1. DIAGRAMMATIC REPRESENTATION OF THE LACTATION CURVE

The upper heavy line curve is the exponential curve, $\frac{dy}{dt} = ae^{-kt}$, typical of the rate of milk secretion outside the inhibitory influence of pregnancy. The symbol y is used for milk yield, t for time in months with calving as origin, a and k are constants, e is the base of natural logarithms, and $\frac{dy}{dt}$ is an expression of the calculus which in this case, means the instantaneous rate of milk yield per month. This equation is admirably adapted to describe the lactation curve because of its close agreement with the observed milk yields and because of the properties of its constants. The constant a represents the initial rate of yield per month; k represents the rate of decrease per month in the rate of yield; and the area under the curve, that is the total amount of milk yielded up to any time (t) is given as a function of the time by the expression $\frac{a}{k}(1 - e^{-kt})$.

The lower or coincident lighter line curve represents the average realized lactation curve. The full rate of milk secretion required by the simple exponential curve above is not realized until a few days after calving [cf. (6) and (7), fig. 4]. This results in the small area or deficiency in yield marked B in the diagram. It is possibly due to a residual inhibition from the preceding pregnancy. Some time after calving the cow again conceives and at a somewhat advanced stage of preg-

The average yield per year for the period from one calving to the next, denoting this period in months by x, becomes:

$$12a\left(\frac{1 - e^{-k(x-2)}}{kx}\right)$$

Ordinarily, k = about 0.1 and assigning it this value and considering a constant, we find that the value of the expression decreases as x increases beyond 10 (about the lowest possible value of x). Or, to leave the matter in mathematical form the expression reaches a maximum when $kx + 1 = e^{k(x-2)}$. This equality with $k = 0.1$ is attained when $x = 7.72$. Even if $k = 0.05$, as is possible under liberal feeding, the maximum is reached at $x = 10.32$. Hence, the highest average yearly yield is obtained by the most frequent breeding, assuming that a remains constant. Ordinarily, of course, a increases with each succeeding lactation up to an age of eight to nine years, so that the desirability of frequent reproduction is further emphasized.

Furthermore, a and k are closely correlated as are also a and y, while k and y are only slightly correlated.[1] It is clear that

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nancy there is again an appreciable reduction from the full rate of yield required by the upper curve. This results in the small area or deficiency in yield marked C in the diagram. It is probably due to an inhibition of milk secretion associated with the current pregnancy. Finally, at two months before term (broken vertical line in the diagram) the cow is dried off, a yield represented by the area D being produced during the process. The cow is dried off in anticipation of the following lactation and a dry period of six or seven weeks is considered sufficient [cf. (5), fig. 16].

An expression for the area under the lower lighter line curve representing the realized milk yield might be derived but it would be rather complicated. As a usable approximation we may assume that D = B + C in the diagram and estimate the lactation yield from the simple upper curve, since B, C and D are small as compared to the total area. If we denote the time in months from one calving to the next by x then the lactation yield becomes $\frac{a}{k}[1 - e^{-k(x-2)}]$. From this expression we may readily generalize as to the effect of variation in length of the calving interval on average yield.

[1] Guernsey records treated on an energy basis, and dealing with yield (Y) for 365 days of the lactation show $r_{ak} = 0.535$, $r_{aY} = 0.672$, $r_{kY} = -0.226$ (paper in press). It was first shown by Gavin (8) that lactation milk yield is closely correlated with the maximum day's yield, $r = 0.839 \pm 0.006$.

high yearly yield is to be attained only from high initial or maximum rate of yield and high initial rate of yield carries with it a rapid rate of decrease in rate of yield with advance in lactation. The larger k the more rapidly the expression of the preceding paragraph decreases as x increases. The necessity of frequent reproduction is therefore still further emphasized.

The foregoing preamble may serve to indicate the significance of the relation of the rate of milk secretion to the occurrence of pregnancy, from the standpoint of economical milk production. If high initial rate of milk secretion interferes with conception in the cow as Hammond has shown it does in the rabbit, then the advantage that is attained by the capacity to high yield at the flush of lactation will be lost, more or less, by the failure to conceive again promptly. The published records of the American Guernsey Cattle Club afford data of value bearing on this point, and certain of these records are presented in the present paper as bearing on the relation of the rate of milk secretion to service period.

SOURCE AND TREATMENT OF DATA

The records are taken from Volumes 33, 34 and No. 1 of 35 of the Guernsey Herd Register, and include all records in the volumes specified in which not more than sixty days elapsed from calving to the beginning of the first full calendar month of the record. The great majority of the records start within a few days after calving. The records of production are published by calendar months and include also data as to time of calving and the effective service following. It is, therefore, possible to correlate the service period with the approximate initial or maximum rate of milk secretion, taking this latter to be the milk yield for the first recorded full calendar month.[2] The records number 4893 of which 222 show no account of effective breeding up to 380 days after calving.

If the rate of milk secretion affects the occurrence of pregnancy

[2] As a saving in the labor of computation the calendar month milk yields are used directly, ignoring the variation in length of the months and in the fat percentage of the milk.

it may be presumed that the effect will vary with the age of the cow, that is, a rate of yield of 1200 pounds per month by a two-year old would be presumed to interfere more seriously with pregnancy than would the same rate of yield in a mature cow. The records have, therefore, been classified according to the age of the cow. For this purpose the classification used in the published records has been followed, viz.: Class A, five years and over; B, four and one-half to five; C, four to four and one-half; D, three and one-half to four; E, three to three and one-half; F, two and one-half to three; G, less than two and one-half years. Class A includes cows up to sixteen years or more of age. Class G includes a small proportion (10 per cent) of cows under two years, with rarely any (0.4 per cent) below one and one-half years. Age is reckoned according to the date at which the record starts.

RESULTS

The means, standard deviations and coefficients of variability for rate of yield and service period are given in table 1, also the coefficients of correlation between these two variables. Cows not bred at 380 days after calving are excluded in table 1. It is apparent from the constants that while the mean rate of yield changes markedly with age, there is no material or consistent change in the mean service period with age. Judged by the coefficient of variability, service period is a highly variable feature of these records.

The coefficient of correlation between rate of yield and service period at the various ages shows a small positive correlation except at the three to three and one-half year old class. The correlation for all ages, $r = 0.039 \pm 0.010$, may be regarded as significant from a technical statistical standpoint, but it is evident for all practical purposes that the first full month's milk yield and service period are independent.

Table 2 gives the mean service period for various age classes at different levels of milk yield. There is given also, in the last column, the number of cows not bred at 380 days after calving, expressed as a percentage of the total number in the respective

TABLE 1

Statistical constants of rate of milk secretion and service period

Guernsey records

AGE CLASS	NUMBER OF RECORDS	MILK YIELD FOR FIRST FULL CALENDAR MONTH			SERVICE PERIOD			COEFFICIENT OF CORRELATION
		Mean	Standard deviation	Coefficient of variability	Mean	Standard deviation	Coefficient of variability	
years		*pounds*	*pounds*		*days*	*days*		
Under 2½	1,120	875	177	20.23	180	80	44.62	0.041 ± 0.020
2½ to 3	523	943	186	19.69	173	80	46.26	0.046 ± 0.029
3 to 3½	434	1,025	191	18.63	162	84	51.61	−0.064 ± 0.032
3½ to 4	416	1,076	207	19.26	169	82	48.63	0.005 ± 0.033
4 to 4½	362	1,146	216	18.86	171	81	47.47	0.033 ± 0.035
4½ to 5	311	1,168	231	19.80	165	81	48.77	0.073 ± 0.038
5 and over	1,505	1,234	231	18.72	177	81	46.13	0.046 ± 0.017
All ages	4,671	1,071	253	23.61	174	81	46.85	0.039 ± 0.010

TABLE 2

Mean service period at various rates of milk secretion and ages

Guernsey records

MILK YIELD FOR FIRST FULL CALENDAR MONTH, CLASS MIDPOINTS	AGE, YEARS								COWS NOT BRED AT 380 DAYS
	Under 2½	2½ to 3	3 to 3½	3½ to 4	4 to 4½	4½ to 5	5 and over	All ages	
	Mean service period								
pounds	*days*	*days*	*days*	*days*	*days*	*days*	*days*	*days*	*per cent*
450	140							140	0
550	185	212		230	10			181	0
650	168	171	179	203	160	90	140	168	4.2
750	184	161	173	158	148	159	178	175	5.4
850	177	175	172	155	162	178	182	174	3.3
950	177	177	162	161	170	151	175	170	3.4
1,050	186	176	156	188	171	156	171	178	5.1
1,150	195	180	158	172	162	153	167	169	5.4
1,250	181	190	147	139	172	185	169	168	4.8
1,350	186	144	182	187	183	189	184	183	2.8
1,450		187	158	180	174	148	171	170	5.5
1,550	170	226	157	114	153	155	182	174	6.4
1,650			110	220		190	194	190	7.8
1,750			110	170	230	194	189	189	9.5
1,850				150	135	170	240	197	12.5
1,950							216	216	12.5
2,050									0
2,150							200	200	0

milk yield class. The proportion of farrow cows does not change with the rate of milk yield except in the last few (highest yield) classes and here the frequencies are too small to make the results

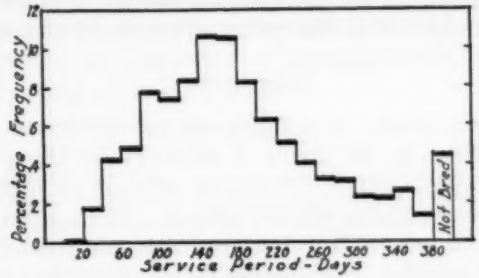

FIG. 2. SHOWING DISTRIBUTION OF 4893 GUERNSEY A. R. RECORDS WITH RESPECT TO SERVICE PERIOD, THAT IS, TIME FROM CALVING TO EFFECTIVE SERVICE

The column at the right indicates cows not in calf at 380 days after calving

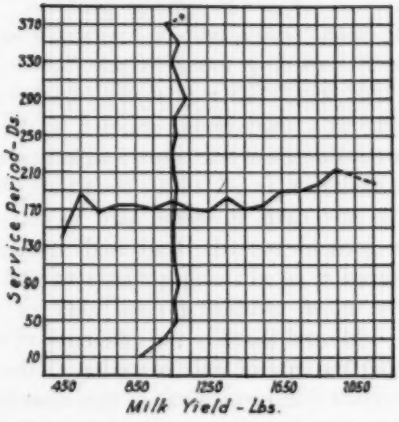

FIG. 3. SHOWING THE OBSERVED REGRESSION LINES DERIVED FROM THE CORRELATION SURFACE FOR THE VARIABLES, FIRST FULL CALENDAR MONTH MILK YIELD AND SERVICE PERIOD

The * shows the mean milk yield, 1111 pounds for cows not bred at 380 days.

of much significance. It may be inferred, therefore, that the absence of these farrow cows in the data of table 1 does not disturb the significance of the correlations there given.

The service period frequency distribution for all ages combined is shown graphically in figure 2, expressed on a percentage basis to the total number of records (4893) as a base. The column at the right represents the 222 cows unbred at 380 days (4.54 per cent) and the area of the histogram represents 95.46 per cent.

DISCUSSION

The present records do not give any information as to infertile services. There is, no doubt, a tendency on the part of the breeders to delay service in the case of cows on official test in order to secure a higher 365-day record. The mean service period, 174 days, is excessively long from the standpoint of economical milk production, and represents one of the consequences of the endeavor of the system of Advanced Registry to obtain a maximum 365-day record. At least there is no apparent reason to suppose that there is any physiological necessity for the unduly long service period of advanced registry practice.

It would seem that there might be a more or less well defined tendency to delay breeding more frequently and for a longer time with cows that start their record at a high level as compared with those starting at a lower level. Such a tendency would lead to a positive correlation between rate of yield and service period. The very low correlation ($r = 0.039$) found may be due to this tendency, but in any case, it seems safe to conclude from the evidence of the present records, that high initial or maximum rate of milk secretion is not antagonistic to the recurrence of conception. The most promising possibility of increasing the average yearly yield, and thereby the efficiency of the cow, seems to lie in increasing the rate of milk secretion at the flush of lactation. It is fortunate if improvement in this direction is not to be neutralized in any wise by a concomitant delay in conception.

SUMMARY

The first full calendar month milk yield and the service period (calving to conception) of 4671 Guernsey A. R. records show a coefficient of correlation of 0.039 ± 0.010. There is no evidence

that high rate of milk secretion interferes with the recurrence of conception in these records. The mean service period is 174 days, standard deviation 81 days, coefficient of variability 47. From generalized premises the service period is far too long for the most economical life time production. The records for the same period show no record of breeding up to 380 days for 222 cows (= 4.54 per cent of 4893).

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THE FORMATION OF ACID IN MILK BY HEATING*

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The changes in the hydrogen ion concentration and acidity caused by heating skimmilk at the boiling temperature and at 95° in open flasks have been presented and discussed briefly in an earlier article (1). The rather small amount of literature on the subject was reviewed, and our experimental methods were described in detail. This article contains similar experimental data obtained at higher temperatures and other data bearing on the buffer action of heated milk and on the source and nature of the acid formed.

In carrying out the heating experiments above the boiling point of milk, it was necessary to use sealed containers. The ordinary 6 ounce evaporated milk cans sealed by a crimping machine were employed. Thus there was no possibility of contaminating the samples with the acid of soldering flux. The cans were heated in a steam jacketed kettle containing glycerine, in which the cans were completely submerged. The steam pressure in the jacket was adjusted by a reducing valve to give the desired constant temperature ($\pm 0.5°$) as measured in the glycerine. All determinations made at the same time interval from the beginning of the heating were carried out on the contents of a single can. With the exception of the acidities on the run at boiling temperature under reflux, in which a Hildebrand electrode was used for the titration, all acidities recorded in this paper were determined by adding to a sample a volume of 0.1 N alkali estimated from previous experience to be sufficient to bring the sample to pH 8.3. The hydrogen ion concentration of the mixture was then determined by means of the Clark electrode. The same procedure was

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repeated with a different volume of alkali until values were obtained between which the exact volume of alkali necessary to give a pH of 8.3 might properly be interpolated. This method avoids diffusion errors and the slow and uncertain approach to equilib-

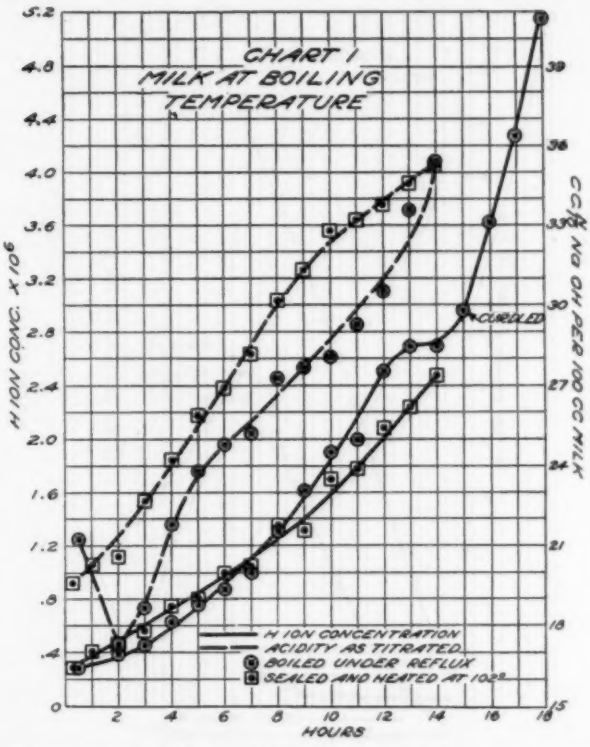

FIG. 1. EFFECT OF BOILING TEMPERATURE ON TITRATABLE ACIDITY AND HYDROGEN ION CONCENTRATION OF MILK HELD UNDER REFLUX AND IN SEALED CANS

rium which was experienced in using the Hildebrand electrode in the earlier titrations.

Obviously the closed containers would retain carbon dioxide and any other volatile constituent of the milk whether present originally or formed during the heating. In order to determine

to what extent previous data obtained at lower temperatures in open containers could be compared with data at high temperatures in closed containers, a run was made at 102° in sealed cans for direct comparison with a run made at approximately the same

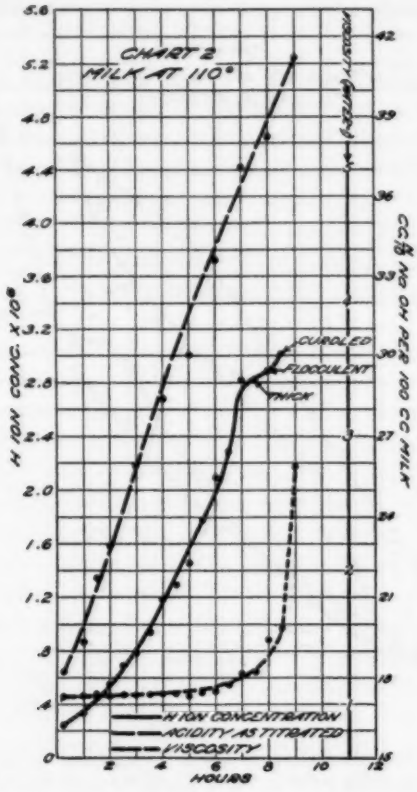

FIG. 2. EFFECT OF HEATING AT 110° ON TITRATABLE ACIDITY, HYDROGEN ION CONCENTRATION AND VISCOSITY OF MILK HELD IN SEALED CANS

temperature (boiling) in a flask under a reflux condenser. The samples of milk were from the same herd but not from the same milking. For these two experiments, hydrogen ion concentration and acidity are plotted against time of heating in figure 1.

It will be noted that the slopes of the curves of each function are practically the same for both samples. The slope of the hydrogen ion curve of the sealed sample is slightly lower than

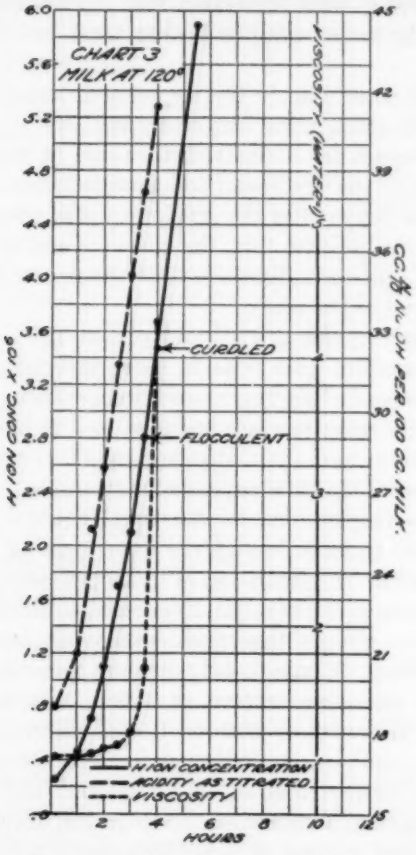

FIG. 3. EFFECT OF HEATING AT 120° ON TITRATABLE ACIDITY, HYDROGEN ION CONCENTRATION AND VISCOSITY OF MILK HELD IN SEALED CANS

that of the other, probably due to a great extent to the buffer action of the carbonate radical, but possibly due in a measure to a different buffer action of the original milks. The acidity levels

are different, as might be expected from the fact that after the first hour carbonic acid was still included in the titration in one set of samples but not in the other. Evidently the chemical changes involving acid formation are practically identical in character in the sealed samples and in those in open containers under reflux.

It should be noted that in this experiment and in the ones following in which the heating was continued after coagulation had taken place, except for a slight disturbance at the incidence of the coagulation, the hydrogen ion concentration continues to follow the same curve after the precipitation of the casein. This appears to us to indicate that the casein is not appreciably involved in the acid formation but that the source of the acid is some constituent of the whey.

Two runs were made at 110° and two at 120°. The runs at any one temperature gave data in close agreement. Figures 2 and 3 show curves for one run at each temperature. The results of viscosity determinations are included on the plots to indicate visually the time and approximate rate of coagulation. Viscosity is plotted as the time required for a sample to pass through a capillary opening divided by the time required for the same volume of water to pass through the same opening.

Values obtained by calculation of hydrogen ion concentrations from measurements of potential differences at elevated temperatures are without a sound theoretical basis under present methods of standardization. Consequently, it is not possible to determine the hydrogen ion concentration at which milk curdles during sterilization. However, a hint as to the effect of raising the temperature of milk on its hydrogen ion concentration may be received from the fact that in both 110° and 120° experiments coagulation began at a time when the hydrogen ion concentration, as measured after cooling, was approximately 2.5×10^{-6}, or pH $=5.60$. Cosmovici (2) has shown that at ordinary temperatures coagulation induced by acid begins at pH 5.35.

No attempt is made to give a detailed explanation of the sudden temporary arrest of hydrogen ion concentration change during the early stages of coagulation. However, it indicates a

powerful buffer action that is manifested only for a brief time. In fact, determinations on the 120° run were not frequent enough to obtain even a suggestion of this feature of the curve. The continued smoothness of the curve of hydrogen ion concentration changes at 120° indicates again that the acid is produced mainly by a constituent of the whey.

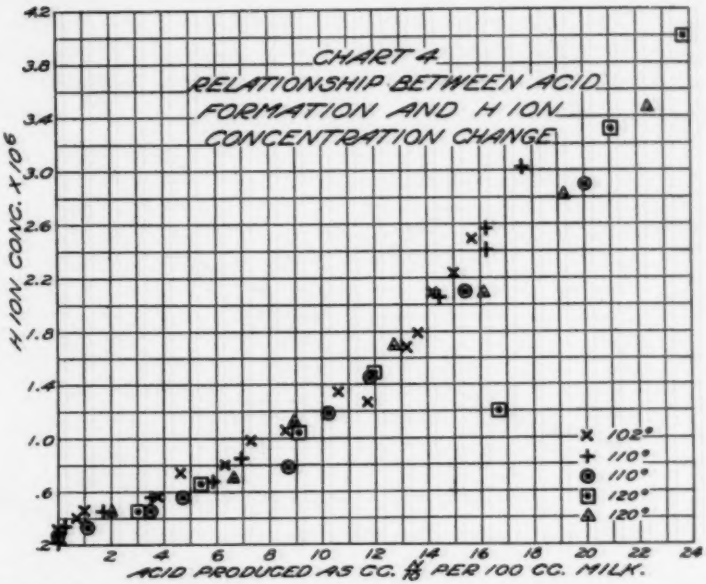

FIG. 4. RELATIONSHIP BETWEEN ACID FORMATION AND HYDROGEN ION CONCENTRATION CHANGE IN MILKS HEATED AT VARIOUS TEMPERATURES

Runs made in open flasks at 95° and 90° show nothing of interest beyond a slower rate of acid formation, and consequently the corresponding curves are not published.

The next point to be considered is the relationship existing between the quantity of acid formed by heating skimmilk and the corresponding changes produced in hydrogen ion concentration. In figure 4 is plotted this relationship for each of the five runs carried out in sealed cans. The grouping of the various points

about a common curve indicates that the buffer action exerted by the milk samples was practically the same at all temperatures employed and that undoubtedly the same acids in very nearly the same proportions were formed in each case. It should be noted that of the two sets of points which stray upwards in the coagulation range, one is plotted from a run at the same temperature as another which clings closely to the flatter slope in the same range. These slight discrepancies are undoubtedly due to differences in the buffer contents of the original milks. Many workers have noted that it is unusual to find two samples of milk identical in buffer content.

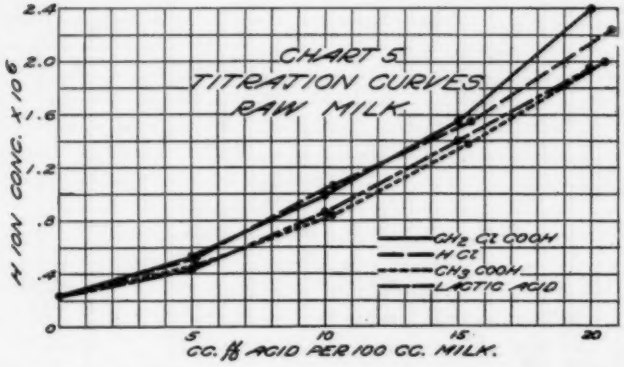

FIG. 5. TITRATION CURVES OF RAW MILK WITH VARIOUS ACIDS

The curve in figure 4 is really the titration curve of skimmilk the titrating acids being those formed during heating. If milk were titrated with an acid having a dissociation constant equal to the mean dissociation constant of the acids formed in the heated milk, a very similar curve should be obtained. It should be identical only in case a single acid is formed and the buffer action of milk is not changed by heating.

In figure 5 are plotted titration curves of raw skimmilk, acids of several different degrees of dissociation being used. Hydrochloric acid was chosen as a strong acid, monochloracetic (pK = 2.81, pK being the logarithm of the reciprocal of the dissociation

constant) as an acid of medium strength, and lactic (pK = 3.82) and acetic (pK = 4.73) as weak acids. It was desired to use acids foreign to milk and of pK values in the region between 5 and 7. However, it was both disappointing and interesting to find that the only common acid radicals which have such dissociation constants are those already present in the milk.

The close similarity of the curves obtained may seem surprising at first, but it must be borne in mind that the principal buffer in milk in the range of these titrations is a mixture of phosphates and that the value of pK for the second hydrogen of phosphoric acid, which is the one principally involved, is about 7.0. Consequently, the buffer action which might be exerted by any of the relatively stronger acids used is almost completely overshadowed by the buffer action of the phosphates of milk. This curve has a much flatter slope than the group of figure 4. Since it has been observed repeatedly that phosphates are precipitated by heating milk, and since it is to be expected that the buffer action is changed by heating, titration curves were carried out on skimmilk that had been autoclaved at 120° for thirty minutes. It will be seen by a comparison of figures 4 and 6 that the curves of autoclaved milk are in good agreement with those obtained from the titration of milk by the acid produced during heating. While these findings duplicate the effect produced by heating milk in so far as the relationship of hydrogen ion concentration to acids formed is concerned, they do not identify these acids. They do, however, locate their mean dissociation constant above 1×10^{-6}. In view of the loss of buffer action caused by heating milk, objection may be raised to the above method of titration on the ground that since the amount of alkali required to change the pH of raw milk from 6.6 to 8.3 is greater than the amount that would be required after heating, the difference between the initial titration on the raw milk and the subsequent titrations on the heated milk does not give the true value for the amount of acid formed. In other words, the values for acid formed are slightly too low. However, the error must be comparatively slight and in any case would not noticeably affect the form of the time curves. The slopes of the titration curves would be

quite unaffected. The primary reason for the choice of end point was that the results might be compared with those of other investigators along similar lines who have used phenolphthalein as the end-point indicator. It should be pointed out that the removal of buffer by heat is not a quickly completed reaction even at 120° but that it involves a time factor.

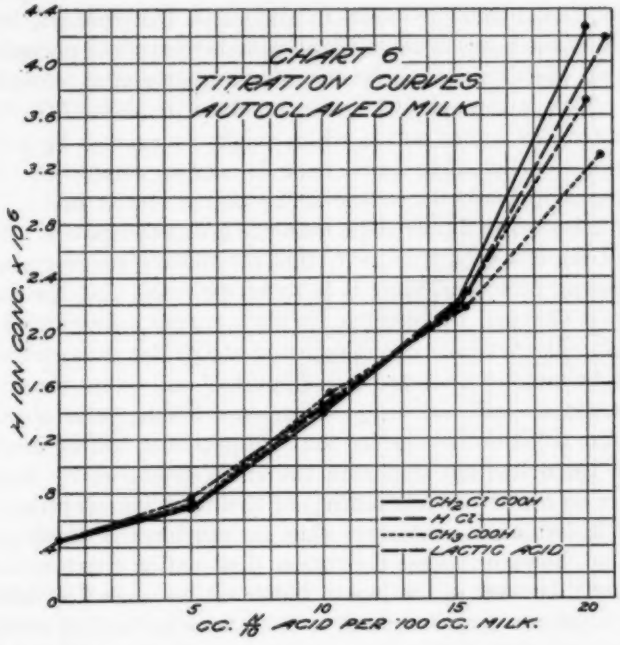

FIG. 6. TITRATION CURVES OF AUTOCLAVED MILK WITH VARIOUS ACIDS

Reasons have been stated for believing that the acid of heated milk is produced from a constituent of the whey. Investigators of the mechanism and conditions involved in sugar oxidation have found that lactose is very easily oxidized, whether in acid or alkaline solutions, to give mixtures of acids. Under weakly oxidizing influences, formic is always one of the acids produced (3). Levulinic acid is characteristic of acid oxidations of lactose;

saccharinic acids, of alkaline oxidations. In the case of heated milk, if lactose is the source of the acid formed, the rate of acid production should be a function of the lactose concentration as well as of the time and temperature of heating. To settle this point, experiments at boiling temperatures were carried out on a sample of skimmilk and a sample of the same milk in which 5 per cent lactose had been dissolved. The heating was carried out in open

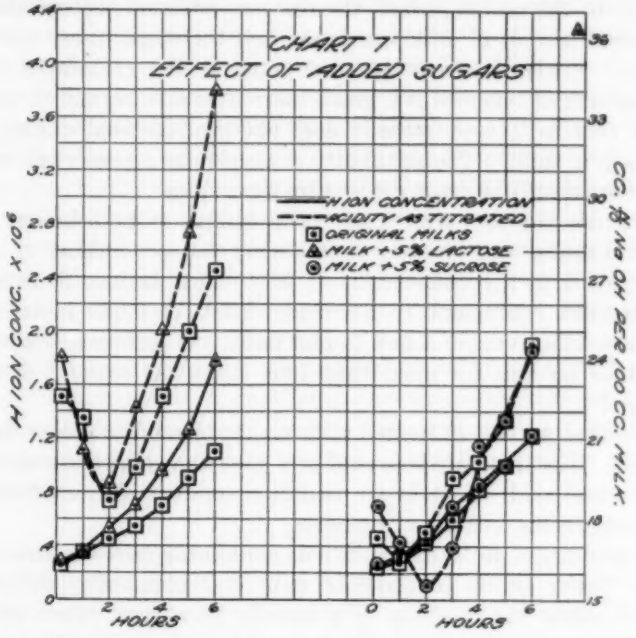

FIG. 7. EFFECT OF ADDED SUGARS ON ACID FORMATION IN HEATED MILK

flasks under reflux condensers, both flasks being heated in the same bath. The rates of change of hydrogen ion concentration and acidity are shown in figure 7. Practically twice as much acid is produced in the milk containing 5 per cent added lactose,— altogether double the normal quantity,— as is produced in the normal milk. Similar experiments were also carried out on 5 per cent lactose solutions containing the same concentrations of total

phosphate, of total citrate, and of hydrogen ions as are present normally in milk, and changes in hydrogen ion concentration and acidity were obtained very similar to those in milk under the same time and temperature conditions of heating. This is considered sufficient proof that lactose is the principal source of the acid formed in heated milk.

The second set of curves in figure 7 is from an experiment analogous to the one on which the first set is based, except that a different sample of milk was taken and the sugar used was sucrose. Evidently, from the standpoint of the condensed milk manufacturer, sucrose is a much more desirable carbohydrate in milk than is lactose, since it does not produce acid during the heating of milk. The suitability of sucrose as a preservation for condensed milk is made evident by these data.

Lactose analyses were made on a sample of milk before and after heating and showed that during the production of acid equivalent to a concentration of 0.02 molal, lactose diasappers in amount equivalent to a concentration of 0.085 molal. In other words, even on a mol to mol basis, the lactose loss is sufficient to account for more than four times the amount of acid formed.

Another portion of heated milk was subjected to steam distillation. The distillate was acid and gave the characteristic tests for formic acid, which is an oxidation product characteristic of carbohydrates, but not of proteins.

Experiments on lactose solutions containing radicals similar in their buffer action to those in milk, but chemically different, would settle the question of a specific phosphate effect on reactions involving lactose. However, the only buffers that meet these requirements are certain complex organic acids, few in number and difficult to obtain. Aside from the variation in rate of color development with phosphate content, nothing in our experiments indicates any specific action of phosphate ions. However, this is as readily explained on the basis of the buffer action of the phosphate, since a continued low hydrogen ion concentration is particularly favorable to caramelization of lactose. Until it is shown that buffering acid radicals other than those

present in milk, but having practically the same dissociation constants, do not exert the same physical and chemical effects on the equilibria, we feel that any claims for specificity of action of phosphates in milk are unproved.

Among the applications of the foregoing may be noted its bearing on the forewarming of milk previous to condensing. It is well known that the stability of milk during condensing and sterilizing is considerably affected by preheating. Certain times and temperatures of heating render the milk more stable; others have the opposite effect. Evidently there is a balancing of factors, opposing in effect, both sets of which are to a considerable degree functions of time and temperature of heating. The above data show that the unstabilizing influences are, at least in part, the formation of acid and the removal of buffer substances during the heating. Attainment of the most successful forewarming conditions depends upon the proper choice of time and temperature to give the most advantageous balancing of the stabilizing effect, whatever may be its character, against these deleterious influences.

Both the acid formation and the loss of buffer are factors that should be considered in modifying milk for infant feeding when previously heated milks are used. Other applications of the data here presented will occur to workers on specific problems of the dairy industry.

RECAPITULATION

Acid is formed during heating of milk at a rate which is a direct function of the time and temperature of heating and of lactose concentration.

The rate of acid formation appears to be unchanged by the coagulation of the casein.

The changes of hydrogen ion concentration and of acidity of heated milk caused by this acid production are of the same order of magnitude as those produced by heating similarly a 5 per cent lactose solution buffered with the same amount of phosphate and citrate and adjusted to the same initial hydrogen ion concentration as those existing in milk.

The relationship between the amount of acid present at any time and the hydrogen ion concentration existing at the same time in the heated milk is comparable with that established by acids with dissociation constants greater than 1×10^{-6}.

Increasing the lactose concentration of milk causes an increased amount of acid to be formed when the milk is heated. Addition of sucrose has no apparent effect on the production of acid in milk by heat.

The loss of lactose content in a heated milk is more than sufficient to account for the acid production, even on a mol to mol basis.

We conclude that lactose is the principal source of the acid produced by heating milk.

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LACTOSE SOLUBILITY AND LACTOSE CRYSTAL FORMATION

II. LACTOSE CRYSTAL FORMATION*

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It was pointed out in Part I of our investigation on "Lactose solubility and lactose crystal formation" (1) that the milk colloids had no noticeable effect on lactose solubility but that sucrose solutions decreased the solubility of lactose to some extent. This decrease was but slight in dilute solutions but became more pronounced as the sucrose concentrations increased.

These findings have a direct, practical bearing on the control of sandiness in ice cream and the control of sandiness and prevention of sediment in sweetened condensed milk. In this work it had been observed that the sugar crystals in sweetened condensed milk which, when it leaves the vacuum pan, normally represents a supersaturated lactose solution containing a sucrose-in-water concentration of about 60 to 64 per cent, were conspicuously different to the eye from the general appearance of lactose crystals as they crystallize from pure aqueous solutions. The latter are of the usual slender tomahawk shape while those found in sweetened condensed milk are distinctly pyramidal and very blunt.

These facts suggested the possibility of the formation, in solutions containing both lactose and sucrose, of mixed crystals of both sugars and of a possible relation between the effect of sucrose on lactose solubility and the form of lactose crystals. These observations, therefore, prompted a study of the crystallography of lactose crystals precipitated from diverse solutions and mixtures, such as pure lactose-in-water solutions, lactose-in-milk, lactose-in-sucrose solutions of high and low concentrations, unsweetened condensed milk and sweetened condensed milk.

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METHOD USED FOR STUDYING LACTOSE CRYSTALS

Materials used and preparation of solutions

The materials used in this investigation consisted of Mercks c.p. lactose, Difco c.p. lactose, Pfanstiehl c.p. sucrose, Domino brand sucrose, whole milk, skimmilk, distilled water, unsweetened condensed milk and sweetened condensed milk. The sucrose-in-water and sucrose-in-milk solutions were so prepared as to have present in the water part of the solution either 14 per cent or 62 per cent of sucrose prior to the addition of the lactose.

All solutions, except the condensed milks, were supersaturated with lactose by dissolving from 30 to 60 grams of lactose powder in 100 cc. of the water part of the solution at a temperature of about 150°F. in the water bath, then cooling to 65°F. and room temperature, respectively, at which temperatures the lactose was allowed to crystallize.

In a few cases crystallization was hastened by seeding the cooled solution with a definite amount of seed material (1 cc.) prepared by rapidly chilling with constant stirring a supersaturated solution of lactose in water. In this way crystallization was always assured and commenced in a much shorter time than when no seed material was added. The seed material had no effect whatever on the crystal form obtained. When using the same amount of the seed material in plain lactose-in-water solutions and lactose-in-sucrose solutions containing 14 and 62 per cent sucrose, respectively, the type of crystals distinctly corresponded with the crystal forms typical for the solution used. However, in general the use of seed material was avoided so as to preclude the possibility of influencing crystal form.

In most cases crystallization was allowed to proceed undisturbed, i.e., without agitating the solution, so as to avoid all danger of breaking or mutilating the crystals.

Sweetened and unsweetened condensed milk were used exactly as obtained from the condensery and without further modification, since these products already contained lactose in supersaturation at the temperature at which their crystal content was studied.

Preliminary crystallization studies showed that there was no advantage in using c.p. sucrose over filtered solutions of Domino brand granulated sucrose. Results obtained with Difco and Mercks lactose also were identical. For this reason the less expensive materials, i.e., Domino sucrose and Mercks lactose were used.

Examination of crystals under the microscope

A drop of the crystalline deposit was transferred to a microscope slide by means of a pipette at intervals during the development of the crystals, observing the progress of crystallization. In addition to this some of the supersaturated solutions were placed on slides and the cover glasses sealed down with vaseline to prevent evaporation. In this way the growth of individual crystals was followed.

The examinations were made under magnifications of 40×, 100×, 440× and 900×.

In studying the crystals under the oil immersion advantage was taken of the fact that by using a certain grade of immersion oil the cover glass could be lifted slightly by regulating the micrometer screw on the microscope, thus causing the crystals to move about in the solution. By careful manipulation of the micrometer screw it was possible to have the crystals turn completely over, thus permitting study from every conceivable angle. This method was of great advantage in studying crystals of as complex a form as that of lactose, since in certain positions their appearance was very misleading.

Photographing the typical crystals

In order to permanently record and illustrate the form of the crystals typical for the various lactose solutions, microphotographs were prepared.

In the case of lactose no difficulty was encountered in obtaining individual crystals. In the case of sucrose the crystals grow together rapidly, making the isolation of perfect individual crystals difficult. In order to avoid this a supersaturated solu-

tion of sucrose-in-water was prepared, and rapidly cooled in ice water with constant stirring, not permitting the crystals to unit. This method avoided the use of foreign substances to increase the viscosity for the purpose of securing individual crystals, which substances might effect a change in the crystal form.

LACTOSE CRYSTALS FROM WATER SOLUTION

Lactose crystals were studied by Schabus (2) as early as 1855 who, however, assigned them to the rhombic hemihedral system. Wulff (3) in a later study reported that they belong perhaps to the monoclinic system while Traube (4) in 1891 described them as being definitely monoclinic. This classification has been found correct by later investigators, as is also shown by Groth (5) in his extensive treatise on "Chemical crystallography" which describes lactose crystals as being monoclinic sphenoidal.

A further study of lactose crystals was made by Hashimoto (6) in 1907 and by Sato (7) in 1914. Sato worked with sweetened condensed milk and reported that the lactose crystals present did not have the same shape and appearance as those obtained when lactose crystallizes from water, milk, and milk serum solutions.

According to the newer method of crystal classification the fully developed lactose crystal belongs to class C_2 since it is enantiomorphous (not identical with its mirror image) and has one binary axis passing through base and apex. The lactose crystal has no center of symmetry and no plane of symmetry, being of a very low order of symmetry.

In their early stages of development these crystals appear as very thin triangles with an extremely small portion of their apex cut off, i.e., they appear trapezoidal. These truncated triangles grow larger in area and thicker, showing a rhomboid base parallel to a barely perceptible rhomboid surface at the apex. As the crystals grow, their base begins to bevel off giving the appearance of a tomahawk and later on the apex assumes a somewhat beveled form also. In the full stage of development the crystal has ten faces. The six sides are trapezoidal, and the base and apex

rhombic. In many crystals the angle of the bevels, or M faces, is such as to seemingly eliminate the faces of the base and apex.

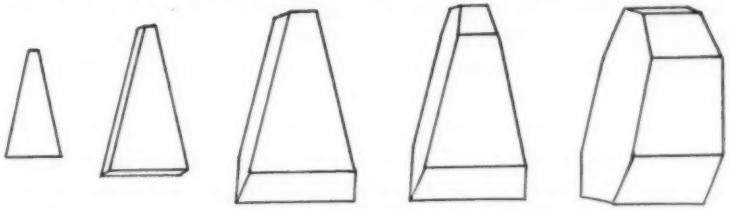

FIG. 1. LACTOSE CRYSTALS FROM LACTOSE-IN-WATER SOLUTIONS SHOWING ORDER OF DEVELOPMENT OF THE CRYSTAL AS PRESENTED FROM LEFT TO RIGHT

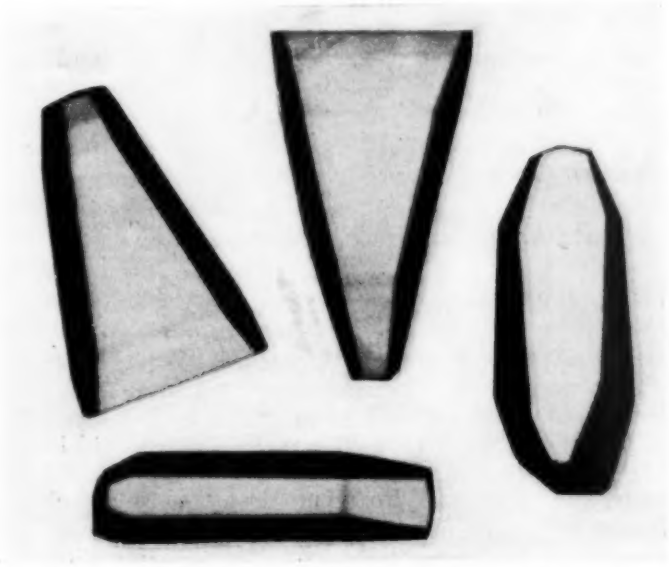

FIG. 2. LACTOSE CRYSTALS FROM LACTOSE-IN-WATER SOLUTION

In our study of lactose crystals from water solutions this type of crystal with the distinct tomahawk end predominated.

In the early stages of development the relation of length to width of the crystals appeared from our measurements to be 1.64

to 1, and their thickness about one-fifth of their length. In the fully developed crystal this ratio was 1.8 to 1 and their thickness about one-third of their length. However, the habit of the crystals obviously may alter these ratios slightly. These measurements are recorded here for convenience of later comparison with lactose crystals from sucrose solutions.

A sketch showing the successive stages in the development of lactose crystals from lactose-in-water solutions is illustrated in figure 1. Microphotographs of fully developed lactose crystals from the same solutions are shown in figures 2 and 3.

FIG. 3. LACTOSE CRYSTALS FROM LACTOSE-IN-WATER SOLUTION

LACTOSE CRYSTALS FROM MILK

By supersaturating whole milk and skimmilk, respectively, with powdered lactose and allowing crystal formation to take place at room temperature, the usual type of tomahawk lactose crystals, characteristic of crystals from pure lactose-in-water solutions were obtained. The same was true of plain condensed milk (unsweetened) containing from 34 to 36 per cent total milk solids and that had been held in the cooler at about 35°F. for a week or longer after being drawn from the vacuum pan. In such condensed milk the lactose is present in a state of supersaturation at the above temperature.

The crystals in both, the fluid milk and the condensed milk, were fully developed at both ends and identical in every respect

to those separated from pure lactose-in-water solutions, as illustrated in figures 2 and 3. Their length also averaged about 1.8 times their width at their widest portion, as is characteristic of typical lactose crystals from pure water solutions.

It is interesting to note also that the lactose crystals from condensed whey shown by Zoller and Williams (8) are identical to our lactose crystals from pure water solutions.

These observations clearly show that solutions containing milk solids yield typical lactose crystals, and that the crystal form is in no way modified or altered by the presence in the lactose solution of milk colloids and milk fat.

LACTOSE CRYSTALS FROM SUCROSE SOLUTIONS

In our study of lactose crystals from solutions containing sucrose, we persistently obtained crystals of a form apparently quite different from the typical lactose crystals derived from lactose-in-water solutions. This study embraced sucrose solutions containing 14 per cent sucrose, 62 per cent sucrose and supersaturated sucrose solutions. The modification of the crystal form became more pronounced as the sucrose concentration increased.

In 14 per cent sucrose solutions the lactose crystals were shorter, decidedly thicker and many of the crystals lacked the beveled faces of fully developed typical lactose crystals from pure water solutions. Figure 5 illustrates the predominating crystal forms usually found to precipitate from 14 per cent sucrose solutions.

Zoller and Williams (8) studied lactose crystals from sandy ice cream containing 14 per cent sucrose and report "the sandy crystals to be identical in form to those of pure lactose." A close study of the crystals illustrated by these investigators, however, reveals unmistakably that the sucrose did have a modifying effect on the form of crystals obtained analogous to our findings with lactose crystals from 14 per cent sucrose solutions.

In the case of 50 per cent, 62 per cent and saturated sucrose solutions, the lactose crystallized out in the form of rhomboidal, pyramidal crystals. As the sucrose concentration increased the

lactose crystals appeared to become shorter and broader. The crystals started as rhomboids and built up from the rhomboid form into truncated pyramids rather than from the triangular form as was observed with crystals from lactose-in-water solutions. Figure 4 is a sketch of the successive stages in the develop-

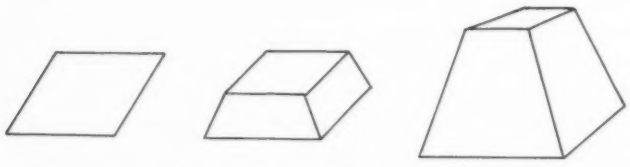

FIG. 4. LACTOSE CRYSTALS FROM SOLUTIONS CONTAINING HIGH CONCENTRATION OF SUCROSE SHOWING ORDER OF DEVELOPMENT OF THE CRYSTAL AS PRESENTED FROM LEFT TO RIGHT

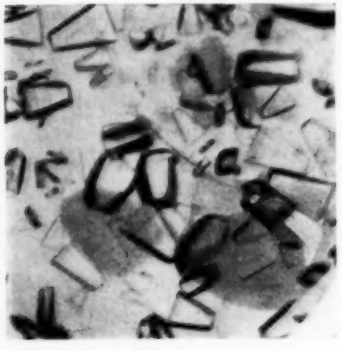

FIG. 5

FIG. 6

FIG. 5. LACTOSE CRYSTALS FROM 14 PER CENT SUCROSE SOLUTION
FIG. 6. LACTOSE CRYSTALS FROM 62 PER CENT SUCROSE SOLUTION

ment of lactose crystals from concentrated sucrose solutions. Figures 6, 7, and 8 are microphotographs of the lactose crystals as found in these solutions.

Thus it was repeatedly observed that where identical concentrations of lactose were present in different bottles containing water and 14 and 62 per cent sucrose solutions, respectively, typical lactose crystals formed in the pure water solutions and the

pyramidal forms developed in the 62 per cent sucrose solutions. In the latter case the length, width and height of the crystal were very nearly equal. In the 14 per cent sucrose solution the crystal showed the typical lactose form but it was generally quite modified in the direction of a blunt type.

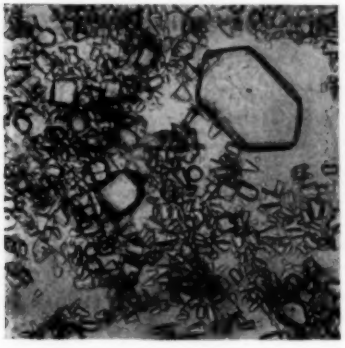

FIG. 7

FIG. 8

FIG. 7. LACTOSE AND SUCROSE CRYSTALS FROM SUPERSATURATED SOLUTION OF BOTH SUGARS

FIG. 8. LACTOSE CRYSTALS IN SANDY SWEETENED CONDENSED MILK

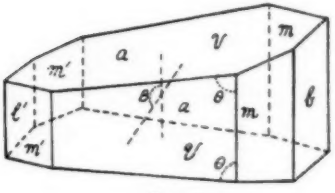

FIG. 9

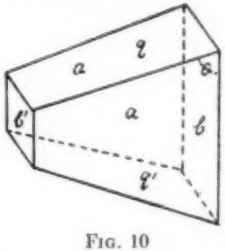

FIG. 10

FIG. 9. LACTOSE CRYSTAL FROM LACTOSE-IN-WATER SOLUTION (BY SATO)

FIG. 10. LACTOSE CRYSTAL FROM LACTOSE-IN-SUCROSE SOLUTION (BY SATO)

It was also noted in one such experiment that during a like period of time the crystals from plain water were very large, some having attained 3 mm. in length, averaging 1.5 mm. From the 14 per cent sucrose solution the average length was 0.5 mm.

The 62 per cent sucrose water solution contained a mass of very small lactose crystals averaging about 0.05 mm.

These observations indicate clearly that the presence of sucrose in supersaturated lactose solutions has a distinct modifying effect on the resulting lactose crystals and that the effect becomes more pronounced as the sucrose concentration increases, causing the triangular form to yield to the rhomboid form and the ratio of length to width to height to change to nearly 1.

Although these crystals appear to differ very materially from those derived from lactose-in-water solutions, crystallographically they belong to the same system, since they too are monoclinic sphenoidal or wedge-shape, and likewise have only one binary axis perpendicular to the rhomboid base and rhomboid top. This pyramidal form of the lactose crystals from sucrose solutions may be considered equivalent to the fully developed crystals, but lacking the beveled faces, or M faces, which are characteristic of lactose crystals from water solutions.

It appears, therefore, that the presence of sucrose affects the habit of the lactose crystal and does not permit it to assume its fully developed form. Sato (7) likewise found that the crystals resulting from crystallizing milk sugar from sucrose solutions were predominatingly of the rhomboid, pyramidal type. Drawings of lactose crystals obtained from aqueous solutions without and with sucrose are shown in figures 9 and 10, respectively.

SUCROSE CRYSTALS FROM WATER- AND LACTOSE-SUCROSE SOLUTIONS

The predominating sucrose crystal has eight faces, with all opposite faces parallel to each other. Base and top are six-sided. All sides of the crystal are rhomboid and its edges and points are often beveled off as illustrated by microphotographs in figures 11 and 12. In contrast to this the typical lactose crystal from highly concentrated or supersaturated sucrose solutions is a truncated pyramid with rhomboid base and apex.

Browne (9) points out that sucrose crystals are capable of assuming a variety of forms. The general description above

given refers to our observations in the study of sucrose crystals from water solutions.

Sucrose crystals grow to relatively very large size while lactose crystals were usually only from one-tenth to one-hundredth as long as sucrose crystals. There is also a persistent tendency of the sucrose crystals to grow together forming large masses of intergrown crystal aggregates, while lactose crystals show no such tendency. They rarely grow together. Where sucrose and lactose crystallize out from the same solution, such relation of size becomes very evident as illustrated in figure 7.

FIG. 11

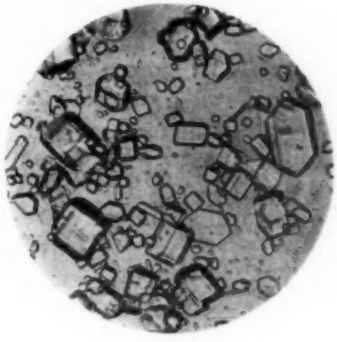

FIG. 12

FIG. 11. SUCROSE CRYSTAL

FIG. 12. SUCROSE CRYSTALS FROM SUCROSE-IN-WATER SOLUTION

Our observations indicate that the sucrose crystals forming in the presence of lactose are typical of the crystals from pure sucrose-in-water solutions. It may be of interest to note here that when sucrose crystallizes in the presence of raffinose, the sucrose crystals become somewhat elongated and pointed, as shown by Browne (9). This may be considered analogous to the modifying effect which sucrose in lactose solutions has on the form of the lactose crystals as previously described under "Lactose crystals from sucrose solutions."

CRYSTALS IN SUPERSATURATED SOLUTIONS OF BOTH SUGARS

Solutions in which both sugars, the lactose and the sucrose, were present in supersaturation, were allowed to crystallize. The crystalline sediment revealed the presence of lactose crystals typical of those found in undersaturated sucrose solutions and of sucrose crystals typical of sucrose crystals from water solutions. Under the microscope these crystals appeared to be entirely independent of each other, as illustrated in figure 7 and there seemed to be a complete absence of modifications suggestive of the presence of mixed crystals of the two sugars. This is in harmony with the general observation that organic substances generally do not form mixed crystals, but crystallize out separately, each yielding crystals characteristic of that substance.

COMPOSITION OF CRYSTALS FROM LACTOSE-SUCROSE SOLUTIONS

Solutions were prepared both in milk and in water containing lactose in excess and with sucrose present to the extent of 62 per cent of the water part of the solution. The sediment of crystals forming here after a crystallization period of five to six weeks was removed by carefully draining off as much of the supernatant liquid as possible and then washing the crystals with ice cold water on the Büchner funnel several times. The crystals were then collected, dissolved in a small amount of water to complete solution and dried at 100°C. in the vacuum oven. This produced the anhydride form of crystals which were weighed as such. These crystals were analyzed for lactose by the use of the gravimetric Fehling's solution method (Association of Official Agricultural Chemists (10)) and showed to contain from 99.2 to 100 per cent pure lactose. These results represent three such determinations. These findings are also supported by the work of Zoller and Williams (8) who found that crystals isolated from ice cream averaged 99.86 per cent lactose.

Since the crystals separating from these concentrated sucrose solutions appeared to be all of the same pyramidal shape and still retained this shape after washing although much of the sharp detail was removed by the wash water, it appears safe to assume

that all the adhering sucrose had been washed away and that the resulting washed crystal sediment was representative of the crystal interior only and not of any of the adhering liquid.

Furthermore, analysis of the supernatant liquid showed that exactly as much sucrose was present in the water part of the solution as was added originally. This is additional evidence that the crystals formed in the concentrated sucrose solution could not have contained any sucrose and that they were not mixed lactose-sucrose crystals but were pure lactose crystals.

SUGAR CRYSTALS IN SWEETENED CONDENSED MILK

Perhaps the most comprehensive study of sugar crystals in sweetened condensed milk was that made by Sato (7) who reports that the sugar crystals in sweetened condensed milk are milk sugar. This he proves by forming the osazone of lactose with a melting point of 200°C. He further states that exactly the same type of crystals were obtained in sweetened condensed milk as the lactose crystals crystallizing from sucrose solutions.

Our observations fully agree with Sato's work. As illustrated in figures 6 and 8 the crystals of lactose present in 62 per cent sucrose solutions are identical in form to the crystals we observed in sweetened condensed milk. We further noted that the height of the pyramidal crystals depended to some extent on the sucrose content of the sweetened condensed milk; the greater the sucrose concentration, the "squattier" the crystals. No fully developed tomahawk-shape crystals were observed in sweetened condensed milk.

This agreement of form between lactose crystals in sucrose solutions and in sweetened condensed milk is in full accord with our observations of the factors affecting lactose solubility where we showed that milk colloids have no effect on the solubility of lactose and that the sucrose alone has a solubility-diminishing effect. Likewise, as shown previously in this paper, the colloids do not have any modifying effect on the type of lactose crystals obtained, but the sucrose does prevent their full development. Hence, it is the sucrose alone that causes the modified form of lactose crystal in sweetened condensed milk.

This is quite in accord with the difficulties observed in ordinary crystallizations, so often encountered in efforts to secure typical crystals, even where only traces of impurities are present. In addition the viscosity of the solution may also be a factor in modifying crystal form.

SUMMARY

1. The crystalline form of lactose was studied. The crystals were precipitated from diverse solutions and mixtures, such as lactose-in-water, lactose-in-sucrose solutions of high and low concentrations, lactose-in-milk, plain condensed milk and sweetened condensed milk.

2. Lactose crystals belong to Class C_2. They are monoclinic sphenoidal and have only one axis of symmetry. They have trapezoidal side faces and rhombic tops and bottoms. The fully developed lactose crystal has in addition beveled faces at the base and apex which may terminate in a sharp edge giving the crystal a distinct tomahawk appearance. It may have ten faces and its length is approximately 1.8 times its width at its widest portion.

3. Fully developed, typical lactose crystals, as described above, are characteristic of the crystals obtained from supersaturated lactose solutions in water, in skimmilk, in whole milk, in milk serum, and in plain condensed milk (unsweetened). It is plainly evident, therefore, that the presence in the milk solution of the milk colloids and milk fat does in no way modify the appearance of the lactose crystal obtained.

4. The presence of sucrose in the supersaturated lactose solution causes an apparent modification in the appearance of the lactose crystals. The crystals so produced are short and stubby and lack the full development at base and apex. In the case of dilute sucrose solutions, such as solutions containing 14 per cent sucrose, this change is only slight, the lactose crystals possessing the full development, but they are shorter and thicker than the crystals from solutions containing no sucrose. This is the type of crystal that occurs in sandy ice cream. In the case of concentrated sucrose solutions, such as solutions containing 62

per cent sucrose, the change in the appearance of the lactose crystal is very marked. The crystals resemble short, truncated pyramids with flat rhomboid base and apex, the beveled faces at base and apex being entirely absent. While crystallographically these crystals are the same, they are apparently not fully developed and give a different appearance, the habit of the crystals being probably the only element affected. This is the type of sugar crystal found in sweetened condensed milk.

5. In contradistinction to the lactose crystals, the sucrose crystals, while also monoclinic sphenoidal, present a vastly different appearance. They do not have pyramidal form, all their faces being rhomboid and all opposite sides generally being parallel. Furthermore, the sucrose crystals grow to relatively very large size and have a great tendency to twine together, which appears not to be the case with lactose crystals. These differences in appearance are very noticeable where lactose and sucrose are allowed to crystallize out from solutions supersaturated with both sugars. Such solutions yield typical crystals of each sugar independent of each other.

CONCLUSIONS

The results of the investigation discussed herein suggest the following conclusions:

1. The presence of milk colloids in saturated lactose solutions does in no way interfere with the full development of the lactose crystals and such solutions yield crystals identical to those obtained from lactose in pure aqueous solutions.

2. The presence of sucrose in saturated lactose solutions has a modifying effect on the appearance of the lactose crystal.

3. For above reasons the modified appearance of the sugar crystals found in sweetened condensed milk is due to the presence of sucrose and not to the milk colloids contained in this product, the sucrose apparently preventing full lactose crystal development.

4. The crystals found in sweetened condensed milk of usual sucrose content (sucrose-water ratio below saturation) are pure

lactose crystals. They are not sucrose crystals, nor mixed crystals of both sugars.

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CHEDDAR CHEESE FROM PASTEURIZED MILK*

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Milk of undesirable quality is frequently delivered to factories engaged in the manufacture of cheddar cheese. This milk commonly contains an overdevelopment of lactic acid producing bacteria or other types of microörganisms which cause objectionable flavors and textures in the cheese. Such milk is often responsible for losses in the manufacturing and the curing of the cheese which would seldom occur if the milk had been of better quality.

The improvement of the quality of a milk supply under some conditions is a matter of great difficulty so that the manufacture of inferior milk into cheese is a problem often encountered. Since the common defects of cheese made from such milk are caused largely by microörganisms, it seems possible to attack the problem by pasteurizing the milk.

This application of the process of pasteurization is not new. Von Freudenreich in 1893 (8) and Fascetti in 1903 (7) were among the first to see the use of the process. In 1907, Dean (5) and Lunde and Holm (14) reported that pasteurization was not effective in improving the quality of the cheese. Liska (12) in 1912 found some improvement in the cheese made from heated milk and Dean in 1912 (6) working with camembert cheese reported that heating the milk to high temperatures improved the quality of the cheese. Other observers (2, 3, 4, 10, 20) have reported varying degrees of improvement in the cheese made from heated milk.

The outstanding work on the pasteurization of milk for cheese making in this country is by Sammis and Bruhn (17). They heated milk to 160° to 165°F. for an instant and after cooling added hydrochloric acid to the milk to stimulate the rennet

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action. Sammis (18) reported later that the process was successful in commercial practice.

In 1923, Stevenson (21) stated that the manufacture of cheese from milk heated to a temperature of 160° to 165°F. for an instant, cooled, and set with rennet, without the addition of acids or salts, was common in New Zealand. He anticipated that within a short time every factory in that country would be equipped to follow the practice.

Some observers have questioned the ability of heated milk to coagulate, with rennet extract, to form a curd suitable for the manufacture of cheddar cheese (2, 3, 9, 11, 14, 17, 19). Others have claimed that the coagulability of the milk is not injured by heating to moderately high temperatures (8, 12, 20). Rupp (16) reported that milk heated to temperatures up to 149°F. coagulated more rapidly than before the heat treatment.

PRELIMINARY EXPERIMENT

Observations were made in this study to determine the rate of coagulation of heated milk with rennet extract. Typical results of these experiments are presented in table 1. The data obtained from two samples of milk are shown. One sample was pasteurized by the flash method and the other by the holder method at the several temperatures and time intervals indicated.

The flash method of pasteurizing has a tendency to delay the coagulation of the milk while the holder method of pasteurizing appears to accelerate very slightly the rate of rennet action when the temperatures of pasteurization approximate 60°C. Since the curd produced from the milk pasteurized by the holder method resembles raw milk curd more closely this method of pasteurizing was used in this study.

EXPERIMENTAL

Method of procedure

In the manufacture of the cheese the usual precautions were taken to have identical milk in each vat. One vat of cheese in each experiment was made from raw milk and every vat of

milk was made into the best cheese possible. This fact is of great importance due to the wide variations in the behavior of raw and pasteurized milk during the cheese making process.

Student's method (22) of interpreting experimental data is used extensively in the discussion which follows. By this method the mean of the differences between paired experiments, in this case the cheese made from the vat of raw milk and the cheese from a vat of milk accorded some other treatment, is calculated. The odds against any such difference occurring due to chance alone are determined from tables published by Student

TABLE 1

The rate of coagulation of heated milk with rennet at 30°C.

TEMPERATURE OF HEATING	DURATION OF EXPOSURE	ACIDITY OF MILK	TIME OF COAGULATION	
°C	*minutes*	*per cent*	*minutes*	*seconds*
Raw	None	0.15	3	50
50	1	0.15	4	20
66	1	0.15	4	40
77	1	0.15	5	30
Raw	None	0.175	4	5
55	30	0.175	3	55
60	30	0.175	3	30
65	30	0.175	3	40

(23) and later extended by Love (13). These odds are stated numerically as 99 to 1 or 500 to 1, etc.

The cheese were scored at intervals during the ripening process by Mr. Horace A. Rees,[1] Professor Walter W. Fisk,[2] Mr. Robert Kirkland,[1] Mr. A. Hargrave and the author.[2] The scores of the judges are interpreted by the ratio method (15). By this method the lowest scoring cheese in a series examined by any judge is assigned a value of 0 and the highest scoring cheese in the same series is assigned a value of 100. The ratio score of a cheese examined by a judge is a numerical value which may be calcu-

[1] New York State Department of Farms and Markets.
[2] New York State College of Agriculture, Cornell University.

lated from the formula $\frac{100\ (s-m)}{r}$; when s is the actual score placed upon the cheese by the judge, m is the score of the poorest cheese of the lot examined by the judge, and r is the difference in points of actual score between the best and the poorest cheese which the judge examined.

The effect of the heat treatment of the milk on the quality of the cheese.

It was assumed that variations in the treatment of the milk with heat affect the quality of the cheese made from it. This

TABLE 2

The average differences between the ratio scores of cheese made from raw, pasteurized and heated milk

HEAT TREATMENT		HEATED MILK CHEESE SCORE MINUS PASTEURIZED MILK CHEESE SCORE	HEATED MILK CHEESE SCORE MINUS RAW MILK CHEESE SCORE
Temperature	Held		
°F	*minutes*		
130	30	−9.4	+0.2
135	15	−15.4	+0.5
135	30	−6.9	+8.9
140	15	−5.1	+5.2
140	30	−0.8	+10.9
145	15	−4.8	+12.4
150	15	−2.2	+15.8
150	30	−6.4	+21.6
155	15	−18.7	−3.5
155	30	−15.2	+4.3

hypothesis was tested by dividing the milk into three identical portions. One portion was not heated; the second was heated to 145°F. for thirty minutes; and the third portion was subjected to a heat exposure whose influence on the quality of the cheese was to be compared with the treatments given the first and second portions of the milk. The results of these trials are presented in table 2.

The cheese made from milk subjected to every variation of of heat exposure, show a tendency to be better than the raw milk cheese, and the greatest improvement seems to be in those

cheese made from the milk whose heat exposure before setting most closely resembled 145°F. for thirty minutes. When these same lots of heated milk cheese are compared with those cheese made from milk pasteurized at 145°F. for thirty minutes it is apparent that their quality is not as good except when the heat treatment approximates 145°F. for thirty minutes. These data would seem to indicate that heating the milk to 145°F. for thirty minutes produces better cheddar cheese than any other holder method of pasteurization.

The term "pasteurization" will be used in the remainder of this discussion to indicate the process of heating milk rapidly to a temperature of 145°F.; holding at that temperature for thirty

TABLE 3

The distribution of the ratio scores of the cheese made from raw and pasteurized milk

SCORES (CLASS)	PER CENT OF CHEESE IN THE CLASS	
	Raw	Pasteurized
20 to 30	3	0
30 to 40	3	0
40 to 50	16	0
50 to 60	28	15
60 to 70	31	20
70 to 80	19	50
80 to 90	0	15

minutes with sufficient agitation to prevent the formation of any scum or pellicle on the surface of the milk; and then cooling as rapidly as possible to 88°F. or below.

The effect of pasteurizing milk on the score of the cheese

There were 46 pairs of cheese among those made in these experiments in which one cheese of each pair was made from raw milk and the other from identical milk which had been pasteurized. The difference between the paired ratio scores of these two types of cheese shows that the pasteurized milk cheese is 14.64 points better than the raw milk cheese, and

Student's method of interpreting the data indicates that the odds against any difference as great as this occurring due to chance alone are more than 10,000 to 1.

The scores of these cheese are arranged in table 3 to illustrate the variations in quality found in each type of cheese.

It is apparent from this table that there is a tendency for the pasteurizing process to produce cheese which is not only better but also more uniform in quality than the raw milk cheese.

The improvement in the quality of the cheese due to the pasteurizing process is also shown by the mean scores of the two types of cheese. The raw milk cheese average ratio score is 58.46 ± 1.51, while the pasteurized milk cheese has a mean ratio score of 71.72 ± 0.95. The fact that the difference between the mean ratio scores does not equal the mean of the differences in score of the paired observations is due to the fact that one lot of raw milk cheese sometimes served as check for more than one lot of pasteurized milk cheese in the course of the experiments.

Variation in cheese quality during the ripening period

The cheese were arranged in groups whose ages were approximately the same, and were scored when two, six and twelve months of age. The mean scores of both types of cheese at these ages are presented in table 4. This table also shows the coefficients of variation of these scores.

The pasteurized milk cheese scores in table 4 show a variation of 5.8 points during the ripening period. Over the same length of time the raw milk cheese scores show a decline in the quality of the cheese of 13.2 points of the ratio score. The coefficients of variation in this same table show that there is a tendency for the quality of both types of cheese to become more variable as the ripening period is extended. The pasteurizing process seems to improve the keeping quality of the cheese.

A more significant comparison of the relative keeping quality of the cheese can be made by determining the mean of the differences in score between the pairs of raw and pasteurized

milk cheese after intervals of two, six and twelve months in the curing rooms. At two months of age the mean difference in the ratio scores between the samples made from identical milk is 11.01 points; at six months the difference is 15.26 points, and at twelve months 18.29 points. At each interval the pasteurized milk cheese is the higher scoring of the pairs. The odds against any differences as great as these occurring due to chance alone are more than 9999 to 1. These comparisons appear to emphasize the tendency indicated in table 4 for the pasteurizing process to improve the keeping quality of the cheese.

TABLE 4

Average ratio scores of the cheese during ripening

AGE	TREATMENT	MEAN SCORE	COEFFICIENT OF VARIATION
months			
2	Raw	66.49 ± 1.69	18.5
	Pasteurized	75.71 ± 0.97	11.2
6	Raw	57.28 ± 2.15	30.5
	Pasteurized	69.89 ± 1.31	18.6
12	Raw	53.30 ± 2.66	29.6
	Pasteurized	71.46 ± 2.48	24.6

The influence of the quality of the milk on the score of the pasteurized milk cheese

When the ratio scores of the paired lots of cheese were studied it was noticed that the difference between the raw and pasteurized milk cheese seemed greatest when the raw milk cheese was of inferior quality. To verify this observation the coefficient of correlation (1) was determined between the raw milk cheese scores and the gain in score of the cheese made from identical milk after pasteurizing. This coefficient was found to be -0.54 ± 0.07 which indicates that as the score of the raw milk cheese decreases the difference in score between it and the pasteurized milk cheese becomes greater.

The coefficient of correlation between the scores of the raw

milk and the pasteurized milk cheese was found to be + 0.63 ± 0.06, showing that as the score of the raw milk cheese decreases the score of the pasteurized milk cheese also decreases.

Clean raw milk which is free from undesirable flavors and bacteria can be made into good quality cheddar cheese. Milk of inferior quality on the other hand will usually produce an inferior grade of cheese. As a general rule, therefore, the score of a raw milk cheese is an approximate indication of the quality of the milk from which it was made. If this is true it may be inferred, from the correlation of the score of the raw milk cheese and the gain in score of the pasteurized milk cheese made from identical milk, that pasteurization of milk for cheese making is most effective when the raw milk is of inferior quality. From the correlation of the scores of the raw and pasteurized milk cheese it may be assumed that milk of inferior quality, even though it is pasteurized, has a tendency to produde an inferior grade of cheese.

The influence of starter upon the quality of cheese made from pasteurized milk

The amount of starter used in the manufacture of cheese is important because of its effect on the acid development during the curd making process. Trials were made to determine the optimum amount of starter to add to pasteurized milk at the time of setting. The starter used was coagulated and about eighteen hours old from the time of inoculation. The results of these trials are given in table 5 as the mean of the differences observed between the scores of the raw and the pasteurized milk cheese made from identical milk.

It seems apparent from the data of table 5 that three per cent of starter is the optimum amount to use at the time of setting. This can be true, however, only with milk which is similar in quality and acid development to the milk used in these experiments. This matter will be mentioned again in connection with the commercial method of manufacture.

The effect of pasteurization on the yield and shrinkage of the cheese

The yield of each lot of milk is calculated on the basis of the pounds of cheese produced by 100 pounds of milk and starter in the vat at the time of adding the rennet extract. The average of the differences in yield between the paired lots of raw and pasteurized milk cheese is 0.304 pound. The odds that this mean difference is significant are more than 9999 to 1. The data in table 6 indicate that this gain in yield is a permanent

TABLE 5

The influence of starter on the gain in ratio score of pasteurized milk cheese

STARTER	MEAN GAIN IN SCORE OF PASTEURIZED OVER RAW MILK CHEESE	ODDS THAT GAIN IS SIGNIFICANT
per cent		
1	14.52	587 to 1
2	15.56	9999 to 1
3	24.42	3300 to 1
4	16.45	30 to 1
5	9.03	9999 to 1

TABLE 6

The yield and shrinkage of raw and pasteurized milk cheese

TREATMENT	SIZE OF CHEESE	MEAN YIELD	PER CENT SHRINKAGE
	pounds	*pounds*	
Raw	10	10.17 ± 0.049	4.8 ± 0.025
Pasteurized	10	10.58 ± 0.046	4.9 ± 0.017

gain and is not lost in shrinkage during the curing process. There is some loss of weight in both the raw and pasteurized milk cheese but it is practically the same in both types.

The gain in yield of the pasteurized milk cheese may be caused by the retention of more of the fat, solids not fat or moisture in the cheese from pasteurized than in the cheese from raw milk. Therefore the pounds of fat, solids not fat and moisture in the cheese made from 100 pounds of milk has been calculated from the percentage composition of the cheese as determined by

analysis for fat and total solids. The results of these calculations are presented in table 7.

These data, which are obtained from the analysis and yields of 28 paired experiments, indicate that the pasteurized milk cheese probably owes its increased yield to the fact that it retains more of the fat, solids not fat and moisture of the original milk than the raw milk cheese. Analysis of the whey from the pasteurized milk at dipping shows that it contains 0.079 per cent of fat less than the raw milk whey. The odds against this difference being due to chance aone are 9999 to 1. This tends to verify a portion of the data of table 7. The solids not fat in the whey from both types of cheese are so variable that the mean of the differences between the pairs is 0.05 per cent with

TABLE 7

Fat, S.N.F. and moisture in raw and pasteurized milk cheese

TREATMENT	CHEESE FROM 100 pounds of MILK AND STARTER	MEAN FAT CONTENT	MEAN MOISTURE CONTENT	MEAN S.N.F. CONTENT
	pounds	*pounds*	*pounds*	*pounds*
Raw	10.20	3.674	3.653	2.873
Pasteurized	10.618	3.897	3.745	2.976

odds of only 4 to 1 that the difference is not due to chance alone. This difference may be regarded as insignificant in accounting for the increase in the amount of solids not fat in the pasteurized milk cheese over the amount in the raw milk cheese.

Commercial practice

In the commercial work carried on by the Department of Dairy Industry at the New York State College of Agriculture, some milk is made into cheddar cheese. During the summer of 1924 the milk delivered to the factory was bad flavored and dirty and developed gas and acid rapidly in fermentation tests. The same defects appeared in the cheese made from this raw milk during the early part of the season. The fat loss in the whey at dipping was abnormally high, ranging from 0.4 to 0.5 per cent.

The making process consumed about ten hours from setting to pressing.

On June 24, 5000 pounds of milk were pasteurized at 145°F. for thirty minutes. The resulting cheese was clean in flavor, and smooth, close, and uniform in body and texture. The amount of pasteurized milk made into cheese during the

TABLE 8

Outline of commercial method of manufacture of pasteurized milk cheese

1. Pasteurization	145°F. for 30 minutes
2. Starter	1 to 3 per cent
3. Rennet	2 to 3 ounces per 1000 pounds of milk
4. Salt	1.5 to 2.5 pounds per 1000 pounds of milk
5. Acidity of milk when received	0.18 to 0.23 per cent
Acidity of milk with starter added	0.18 to 0.235 per cent
Acidity of whey at cutting	0.125 to 0.145 per cent
Acidity of whey at dipping	0.145 to 0.170 per cent
6. Temperature when starter is added	86° to 88°F.
Temperature at renneting	88°F.
Temperature after cooking	103° to 106°F.
7. Time from setting to cutting	15 to 30 minutes
Time from cutting to stirring	2 to 5 minutes
Time from stirring to cooking	10 to 15 minutes
Duration of cooking	30 to 45 minutes
Time from cooking to dipping	40 to 60 minutes
Time from dipping to packing	10 to 15 minutes
Time from packing to milling	60 to 150 minutes
Time from milling to salting	10 to 20 minutes
Time from salting to hooping	10 to 45 minutes
Time from hooping to dressing	25 to 50 minutes
Time from setting to pressing	5 to 6 hours
Duration of pressing	14 to 16 hours

rest of the season totaled 1,121,629 pounds. This milk contained 3.79 per cent fat and showed a yield of 10.126 pounds of cheese per hundred of milk. It is interesting to note that for the three months previous to the period of the manufacture of cheese from pasteurized milk, there were 754,750 pounds of raw milk containing 3.68 per cent fat made into cheese with an average yield of 9.724 pounds of cheese per hundred of milk.

The method of manufacture developed experimentally and practiced on the large scale is outlined briefly in table 8.

Examination of the outline of the making process should not lead to the incorrect conclusion that it is possible to make the finest grade of cheese in the minimum time allotted each operation. The time element in curd making is of secondary importance because the character of the curd determines primarily the speed of the cheese making process.

Variations in the chemical and physical characteristics of the milk make necessary certain small but important adjustments in the process. Some of these variations which are indicated in the outline may well be discussed.

1. The pasteurizing temperature seems most effective when maintained at 145°F. for thirty minutes.

2. Enough starter is added to the milk before setting to produce 0.165 per cent of acid in the whey at the time of dipping.

3. Enough rennet is needed to obtain a curd firm enough to cut in from fifteen to thirty minutes from the time of adding the rennet.

4. Curd requires enough salt to suit the trade demand. Since the yield of cheese may vary from day to day, the amount of salt is also varied.

5. The ability of raw milk to develop acid rapidly is destroyed by pasteurization. Successful curd making depends on the presence or the development of sufficient acid to bring about the normal loss of moisture from the curd. It is necessary, therefore, in order to obtain the correct acid development at dipping, to adjust the amount of starter used to the initial acidity of the milk and the time the curd is expected to be in the whey.

6. The temperature of the milk when the starter is added is near the setting temperature because usually no time interval is necessary for acid development before adding the rennet.

The setting temperature which seems most advantageous is 88°F. At lower temperatures the curd has a tendency to be tender like a very sweet, raw milk curd. Higher temperatures affect unfavorably the rate of draining of the moisture from the curd.

The cooking temperature varies with the fat in the milk, the acidity developed, and the character of the curd. The cooking temperatures of 103° to 106° seem to be desirable with pasteurized milk because of its tendency to retain moisture due largely to the slow acid development in the whey.

7. The time consumed by each operation after adding rennet depends on the character of the curd and the rate of acid development in the whey. Regardless of the time element the curd at dipping must be firm or "shotty," while the whey has preferably not more than 0.17 per cent acid or when the curd strings not more than $\frac{1}{8}$ inch on the hot iron. This desired firmness and acid development is attained in two to two and one-half hours from the time of adding the rennet.

The time allowed for cheddaring depends on the desire of the maker to produce a close textured cheese. Holding for long periods gives a close testure, shorter periods result in more open textures. Proper cooling of the curd between milling and salting, thorough distribution and solution of the salt, followed by slow application of pressure in the hoop result in better cheese than those finished by a more hasty and careless process.

CONCLUSIONS

1. Pasteurization at 145°F. for thirty minutes produces better quality of cheese than does any other method of pasteurizing tried in these experiments.

2. Pasteurized milk produces more uniform cheese, of better average quality, which keeps better under storage conditions than raw milk cheese.

3. Pasteurization is most effective when the raw milk is of inferior quality but the quality of pasteurized milk cheese varies with the quality of the raw milk.

4. Pasteurization increases the yield of cheese.

5. Manufacture on a large scale demonstrates that pasteurization of milk for cheddar cheese making is practicable, economical and profitable.

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EFFECT OF MINERAL DEFICIENCY ON THE YIELD AND COMPOSITION OF COW'S MILK*

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The relation of mineral deficiencies in the ration to the yield of milk is a question of considerable economic importance. It is also important to know from the nutritional standpoint whether the mineral elements of the milk ash—especially calcium and phosphorus—are affected by an insufficient supply of these in the feed consumed by the animal.

It has long been observed in some of the extremely mineral deficient areas of Europe and Africa that the milk yields are reduced markedly when outbreaks of osteomalacia occur. Tuff (1) noted that a decrease in milk yield was a common result of shortage of lime and phosphoric acid in the roughages fed to cows in a part of Norway. If a mineral supplement such as bonemeal or herring meal was fed, the yield of milk was greater. With cows on pasture where osteomalacia did not occur, the milk yield was satisfactory even without such mineral supplements. Theiler (2) observed that ten cows receiving a ration otherwise very deficient in phosphorous produced 40 per cent more milk when the ration was supplemented with bonemeal than did another similar group of cows without bonemeal. Weiske (3) noted that cows decreased in milk flow when receiving a ration low in calcium and phosphorous and Fingerling (4) noted the same results with goats.

Hasselbalch (5) divided a large herd of Jersey cows into two groups, one group receiving a commercial mineral mixture. This

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group yielded an average of 13 kgm. per cow more "butter" in the following one hundred and eighty days than did the controls. Two other groups of cows receiving dibasic sodium phosphate during the dry period yielded 5 kgm. more butter each than in the preceding lactation. Seven first-calf heifers excelled the yield from 9 control heifers by 4.3 kgm. of butter. He concluded that under his conditions the mineral supplement resulted in an increase of 10 to 15 per cent in butter yield. There are districts in Denmark where cattle suffer from lack of minerals in the feeds grown locally, but Hasselbalch did not state whether his herd was located in such an area.

Meigs and Woodward (6) supplemented the rations of dry cows with sodium phosphate. On comparing the milk yields between the tenth and fortieth days of the subsequent lactation with those of the previous, they noted a 37.9 per cent increase in milk yield over the expected quantity. Meigs (7) found that the decline in milk production was less rapid on a high calcium ration when supplemented with calcium carbonate and most rapid on the low calcium ration with mineral supplement.

A number of investigations are also reported dealing with the relation of the mineral content of the ration and the ash of milk. With the exception of one experiment reported in 1891 the results indicate that the mineral content of milk both in amount and percentage of constituents is not varied with the mineral intake. Among those reporting these results are Golding and Paine (8), Trunz (9), Weiske (10), Orla-Jensen (11), and Jordan and associates (12).

Most of these investigations either covered short periods or were made with cows presumably in normal condition at the beginning of the feeding period. In view of the present knowledge concerning the extent to which a cow will store mineral matter in time of ample supply and draw upon it in times of deficiency, experiments made under such conditions can hardly be looked upon as conclusive. Only in the report of the experiments by Jordan is there any evidence that the cows used were suffering from mineral deficiency to the extent of showing typical symptoms.

For these reasons it appeared worth while to present data taken in connection with an investigation of a deficiency in the rations of dairy cattle which is common in parts of Minnesota (13). The symptoms are lack of thrift, low condition of flesh, undersize, abnormal decline in milk production, stiffness in joints sometimes severe, an extremely abnormal appetite evidenced by persistent chewing of bone, eating wood and dirt. The general term osteomalacia is among those used in the literature in designating this condition. The investigations reported in full by Becker show the trouble to be the result of a shortage of phosphorus in the forage grown in the region affected due to the small content of the same element in the soil. The chief forage used is prairie hay, although the trouble occurs at times when alfalfa is fed. The soil is not acid and legumes grow freely.

EXPERIMENTAL RESULTS

The data presented were taken from four cows. The animals received a basal ration of prairie hay and oats grown on farms where the trouble has commonly occurred. Three showed the symptoms of advanced osteomalacia when purchased and the same condition was produced with the fourth animal by restricting her feed to the basal ration for several months. The cattle had free access to common salt and were watered twice daily. In all favorable weather they were allowed exercise for several hours daily in an open pen in the direct sunlight. Five-day composite milk samples were collected monthly and preserved with formaldehyde for mineral analyses. After the first series of milk samples were secured, the basal ration was supplemented with an inorganic mineral supplement, and milk samples again taken at regular intervals. With two of the cows, a phosphate supplement was later substituted for calcium carbonate, and further milk samples taken. The two animals receiving calcium carbonate as a supplement to the basal ration declined in vigor and condition indicating the deficiency was not in the calcium. Marked improvement and complete recovery from any visible symptoms of active osteomalacia was effected when the basal ration was supplemented with either mono-basic sodium phosphate or tricalcium phosphate.

Twenty-four milk samples were analyzed for total solids, total ash, phosphorous and calcium, according to the standard methods by the Division of Agricultural Biochemistry. The butter-fat content of the milk was determined by the Mojonnier method. The results of the analyses are summarized in table 1.

The data given show no indications of an increase in the calcium or phosphorous content of the milk attributable to the addition of calcium carbonate, calcium phosphate, or mono-basic sodium phosphate to a ration of prairie hay and ground oats. In

TABLE 1

Effect of mineral supplements on the yield and composition of milk

MINERAL SUPPLEMENT FED	NUMBER OF SAMPLES	DAILY MILK YIELD	TOTAL SOLIDS	FAT	ASH	P_2O_5	CaO
		pounds	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Cow E-32:							
Basal ration	4	16.96	13.310	3.519	0.717	0.236	0.172
$Ca_3(PO_4)_2$	3	20.01	12.87	4.212	0.736	0.193	0.143
Cow E-58:							
Basal ration	1	3.94	16.74		0.875	0.260	0.210
$CaCO_3$	2	4.30	15.215	4.430	0.73	0.190	0.160
NaH_2PO_4	4	5.13	14.52	4.158	0.716	0.223	0.163
Cow E-59:							
Basal ration	1	6.36	16.210		0.875	0.275	0.202
$CaCO_3$	4	7.44	13.96	5.087	0.780	0.244	0.185
NaH_2PO_4	1	6.98	13.995	5.046	0.780	0.246	0.182
Cow E-62:							
Basal ration	2	5.68	14.538	4.87	0.785	0.235	0.182
NaH_2PO_4	2	6.55	14.273	4.78	0.750	0.230	0.180

three out of four instances, there was an increased milk yield attributable to the addition of a phosphate supplement to a ration low in total phosphorous.

The small increase in milk flow on the addition of calcium carbonate to the ration of cows E-58 and E-59 may be due to the first sample having been taken but a few days after the animals had been shipped to University Farm.

With cow E-59, a milk sample was taken made up of aliquot parts of each milking for the last ten days while calcium carbonate was being fed, and in the following ten days when she received

mono-basic sodium phosphate. The nation received, exclusive of the mineral supplement, was the basal ration known to be mineral deficient. The results on the yield and composition of the milk are shown in table 2.

These data fail to show any change in the mineral content of the milk as the result of changing from the calcium carbonate to the sodium phosphate supplement.

TABLE 2

Yield and composition of milk of cow E-59 when fed calcium carbonate and sodium phosphate

MINERAL SUPPLEMENT	YIELD OF MILK	FAT	TOTAL ASH CONTENT	P_2O_5	CaO
		per cent		*per cent*	*per cent*
$CaCO_3$	69.1	5.09	0.780	0.248	0.193
NaH_2PO_4	69.8	5.06	0.780	0.246	0.182

TABLE 3

Calcium and phosphorus in milk from mineral deficiency rations compared to normal

	NUMBER OF SAMPLES INCLUDED	TOTAL ASH	P_2O_5		CaO	
			Per cent	Per cent of total ash	Per cent	Per cent of total ash
		per cent				
Check sample	1	0.717	0.215	29.9	0.170	23.6
Cow E-32	4	0.717	0.235	32.6	0.172	23.9
Cow E-58	1	0.875	0.260	29.7	0.210	24.0
Cow E-59	1	0.875	0.275	30.8	0.202	23.0
Cow E-62	2	0.740	0.235	31.7	0.182	25.1

At the time the experimental samples were prepared for analysis a sample was taken from the mixed milk of the University Herd representing approximately 1000 pounds daily produced by forty cows of four breeds. This sample analyzed with the experimental samples by the same analyst serves as an excellent check with which to compare the experimental samples. In the comparison shown in table 3 is given the analysis of the check sample together with those of the experimental samples taken from the cows at a time when they were showing marked evidences of mineral deficiency.

The data in table 3 do not bring forth any evidence that the ash of the milk from the cows suffering from extreme and long continued mineral deficiency is changed to any appreciable extent from the normal.

CONCLUSION

The data given indicate that a shortage of phosphorus in the ration extending over a long period of time may become the limiting factor in milk production. Even under conditions of osteomalacia so severe as to show marked symptoms in the animal resulting from an extreme and long continued shortage of phosphorus the calcium and phosphorus content of the milk remains normal in amount and in proportion.

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PROCEEDINGS OF THE ANNUAL MEETING OF THE AMERICAN DAIRY SCIENCE ASSOCIATION

The twenty-first annual meeting of the American Dairy Science Association was held in the Book-Cadillac Hotel, Detroit, Michigan, October 7, 8 and 9, 1926.

The first general session was devoted to business and committee reports and a splendid address on "Science All the Way Through," by Dr. K. L. Butterfield, president of the Michigan State College.

The Secretary's report showed a substantial growth in the Association over the previous year, amounting to about 30 per cent. This places it on a sounder financial basis in the performance of its functions.

President O. E. Reed appointed the following committees:

Nomination: Borland, Davis, Fitch, Rogers, C. W. Larson.

Resolution: Guthrie, C. W. Larson, Eckles.

National Research Council: Term expiring 1928, C. W. Larson; term expiring 1929, R. S. Breed and G. C. White.

The banquet, at which three humdred were present, served as the setting for the announcement of awards in the judging contests, as usual.

The second general session was devoted to reports of sections and new business as follows:

Adoption of resolutions pertaining to the death of W. A. Stocking, an expression of appreciation to the Book-Cadillac Hotel Management, and an expression of a need for the modification of the present representation plan in force by the Division of Biology of the National Research Council.

A Program Committee of three members was appointed with the following personnel: C. H. Eckles, three years; H. A. Ruehe, two years, and C. C. Hayden, one year.

The committee on relations with the National Milk Dealers' Association was continued with one change. The members are H. A. Ruehe, E. S. Guthrie, and G. D. Turnbow.

A resolution was adopted asking the executive committee

to consider the advisability of holding a summer meeting of the American Dairy Science Association in order to avoid the conflicting activities in connection with the National Dairy Show.

I. PRODUCTION SECTION

Chairman C. C. Hayden gave a brief synopsis of papers by G. C. White, E. B. Meigs, and E. B. Forbes. The new officers elected are Chairman, A. C. Ragsdale, Columbia, Mo., and secretary, H. W. Cave, Manhattan, Kansas.

II. MANUFACTURING SECTION

Chairman A. C. Baer reported for this section.

The Official Score Card for milk was amended so as to read: The official score card for milk shall give a perfect score for fat and for solids-not-fat whenever such samples comply with local requirements where contest is held.

The officers elected are Chairman, E. S. Guthrie, Ithaca, N. Y., and secretary, W. H. E. Reid, Columbia, Mo.

III. EXTENSION SECTION

Chairman A. J. Cramer presented a synopsis of the following committee reports: Milk Campaigns, Feeding, Cow Testing Associations, Bull Associations, Calf Clubs, and Dairy Manufacturing.

The officers elected are Chairman, A. J. Cramer, Madison, Wis., and secretary, C. R. Gearhart, State College, Pa.

IV. ADVANCED REGISTRY SECTION

Chairman Wylie presented the report for this section.

Changes in rules adopted follow:

1. That the supervisor should refrain from talking during the milking operation.
2. That a blank test be run on the sulfuric acid.

A resolution requesting the Breed Associations to publish the revised rules of the American Dairy Science Association in their respective handbooks. Other important papers and reports were received.

The officers elected are Chairman, P. S. Williams, State College, Pa., and secretary, J. M. Fuller, Durham, N. H.

(Signed) G. C. WHITE, *Secretary.*

PRODUCTION SECTION

The Production Section of the American Dairy Science Association held its annual meeting at 2:00 p.m., Friday, October 8, 1926 at the Book-Cadillac Hotel, Detroit, Michigan.

Chairman C. C. Hayden, presided. The minutes of the previous meeting as read by Secretary O. G. Schaefer, were approved.

G. C. White of Storrs, Connecticut read a paper on Abortion Eradication in which he emphasized the following fundamental points which have been firmly established with reference to the disease:

1. New born calves are not permanently infected by their dams, and they enter a susceptible stage only after sexual maturity is reached and particularly after they have become pregnant.
2. When the disease is once established in an individual or a herd, it is apt to be permanent, and although the animal may become capable of producing normal, living calves, it continues to harbor the infection and to spread the disease to susceptible animals which enter the herd.
3. The B. abortus germ is responsible in whole or in part for at least 90 per cent of the premature calvings occurring before the 265th gestation day.
4. The blood tests are a reliable means of diagnosing the abortion infection.

E. B. Forbes presented an interesting paper on Mineral Requirements for Dairy Cattle which he summed up as follows:

The present evidence warrants emphasis on the use of leguminous roughage; on as much exposure of the cows as is practicable to direct sunlight; on as much use as possible of green feeds; on the curing of hay with the minimum of exposure to dew and rain, and on the allowance of a dry, resting period, and of feed during this period, sufficient to permit the complete restoration of the previous mineral losses.

The present evidence warrants the use of mineral feeds only on an experimental basis, and does not warrant the inclusion of mineral components in commercial feeds.

The committee on Minerals for Dairy Cows was asked to continue its work of reviewing and summarizing the work done on this subject, in order to determine if possible, in a short period of time, what are the necessary minerals for dairy cows. The members of this committee are:

E. B. Meigs, United States Department of Agriculture
C. H. Eckles, St. Paul, Minnesota
C. F. Hoffman, East Lansing, Michigan
H. B. Ellenbarger, Burlington, Vermont
C. F. Monroe, Wooster, Ohio

"Future Coöperative Work in Mineral Nutrition" was the title of a paper by E. B. Meigs in which he said,

> In the present stage of scientific progress, work on the mineral requirements of dairy cattle should be made to center about the subject of calcium and phosphorus metabolism. Other mineral elements no doubt play a very important part in the nutrition of these animals, but in no other field is there so much promise of important practical information from a moderate amount of further work as in the subject of calcium and phosphorus metabolism.
>
> The results of the work so far carried out on this subject indicate that dairy cows, and particularly high producing dairy cows are likely to suffer from a deficiency of calcium in their rations under conditions of feeding and management which are widely prevalent in many parts of this country. They indicate further that the full effects of this deficiency are likely not to appear until after the animals have been on such rations for a long time, and are of such a character that they would not be attributed to faulty feeding, unless the connection was experimentally proved. It is of the greatest importance, therefore, that our information on the questions, what constitutes a ration deficient in calcium, what are the effects of feeding such rations, and how are these effects to be avoided, should be as definite as possible.

The following officers were elected for 1927: A. C. Ragsdale, Columbia, Mo., Chairman; W. H. Cave, Manhattan, Kansas, Secretary.

Meeting adjourned.

O. G. SCHAEFER, *Secretary.*

MANUFACTURING SECTION

The meeting of Section II of the American Dairy Science Association was called to order by Chairman A. C. Baer at 2 P.M., October 8, 1926 at the Book-Cadillac Hotel, Detroit, Michigan.

Minutes of the twentieth meeting were read by F. J. Doan, Acting Secretary in place of C. D. Dahle, and approved.

J. H. Frandsen reported for the committee on Score Cards and Legal Standards, to the effect that the official score card for milk should be amended to agree with the new government card used by the Bureau of Dairy Industry in which a perfect score is given for the items: fat and solids-not-fat whenever samples comply with the local requirements in respect to these ingredients.

Report was adopted and sent to general session for approval.

A. C. Dahlberg, Chairman of the general committee on Chemical Methods of Testing Dairy Products reported on the organization of this committee and its relation to the sub-committees. The committee suggested the appointment of a sub-committee to study methods of testing skim milk, butter milk and whey for fat. They further suggested that attention be given in the near future to standard methods for analysis of butter for salt, water and fat; and of cheese for total solids and fat. The report was approved.

A. C. Dahlberg reported as chairman of the sub-committee on The Comparative Accuracy of the Gerber and Babcock Tests. The two tests were found to be comparable from the standpoint of accuracy but for obvious reasons it was the opinion that one good practical test for fat in milk and cream is better than two of equal merit. The report was approved.

The report of the sub-committee on Official Methods of Testing Milk and Cream for Fat was given by Chairman F. W. Bouska. The committee first recommended the publication of a pamphlet containing the official methods of the American Dairy Science Association to be sent to all college dairy departments and government laboratories and to commercial laboratories making application.

This matter was approved subject to approval by the general session.

Recommendations were also made relative to changing the official A. D. S. A. Babcock method for fat in milk and cream in certain particulars.

After some discussion the recommendation was adopted subject to approval of general session. (Note: In general session the recommendations were not approved but were referred back to committee with suggestion that A. D. S. A. methods and A. O. A. C. methods be kept identical and that opinion of the latter organization be obtained before definitely changing the methods as they stand.)

Further suggestions of this committee favored the study of the butyl alcohol test for buttermilk, modified Babcock methods for buttermilk, skim milk and whey, and modified Babcock methods for evaporated milk.

Committee report was approved.

R. C. Fisher, Chairman of the Committee on Testing Ice Cream for Fat and Solids reported results of a survey made to determine what tests were being used for fat in ice cream, and what sort of comparative results were being had. In general, survey showed that the Glacial-Acetic-Sulphuric Acid test, the Alcohol-Sulphuric Acid test and the Glacial-Acetic-Sulphuric-Nitric Acid test were the most used. The committee is to continue its study with a view of making recommendations for standard official methods at a future date. Report approved.

The committee on Methods of Determining Milk Solids not Fat made no report.

R. S. Breed, chairman of the general committee on Bacteriological Methods reported for this committee concerning the organization and work of the various sub-committees, existing and contemplated. He also reported for the sub-committee on milk and cream, stating that this committee had the opportunity of examining the manuscript of the proposed new edition of the Official Methods of the A. P. H. A. Several changes were noted from former editions but these must be approved at the meeting to be held at Buffalo, October 1926. Report approved.

The sub-committee on Ice Cream represented by Chairman A. C. Fay reported on the drawing up of bacteriological methods for ice cream but suggested that they be published in the Journal for examination by members and discussed at a future meeting. Report approved.

Report of the Committee on College Creameries was read by the secretary. The report of this committee made last year together with the resolutions was sent to the National Ice Cream Manufacturers Association, the International Association of Milk Dealers and the American Creamery Buttermakers Association asking for a similar resolution from their respective associations. The executive committee of the milk dealers association refused to recommend the report to the association for action. The other two remain to be heard from definitely. Report approved.

R. B. Stoltz presented the majority report of the committee concerning National Contests for Judging Dairy Products. The committee favored the scoring of seven samples of each product instead of ten and the subsequent reduction of the time from one hour to forty-five minutes. They also favored the idea of the coaches being allowed to score the products during the student contest. After considerable discussion action was taken giving the committee power to draw up rules and regulations for the contest next year.

R. C. Potts, Chairman of the Committee on Economic Phases of the Dairy Industry presented a very interesting report on the experiment station Purnell projects and how they were distributed among the various agricultural departments. Report approved.

Chairman Baer appointed the following Committees:

Nominating Committee: J. H. Frandsen, R. C. Potts, H. F. Judkins

Resolution Committee: F. W. Bouska, O. F. Hunziker, M. Mortensen

W. H. E. Reid of Missouri presented a paper concerning the effect of processing on the dispersion of fat in an ice cream mix. High points in the conclusion were as follows:

Processing decreased the size of the fat globules but brought about greater clumping of the globules.

Processing increased the surface tension of the mixes.

Processing lessened the stability of the ice cream but made for smoother texture and greater control of the freezing process.

A discussion topic on the relation of sugar to overrun and quality was well presented by P. L. Lucas of Michigan.

Results of experimental work showed that sugar hinders the development of overrun but betters the texture. Excessive amounts however, slow up the freezing process due to lowering of the freezing point, produce a gummy, heavy body, make the cream hard to hold in the dealer's cabinets and lessen the standing up qualities. A sugar content of 14 to 16 per cent was deemed the optimum amount.

H. H. Sommer of Wisconsin presented a very interesting discussion topic concerning the effect of milk salts on the whipping ability of ice cream mixes which was illustrated by means of graphs.

Sodium citrate and sodium phosphate accelerate the whipping while calcium salts retard it. Neutralized cream therefore has a retarding effect. It was very clearly brought out in the graphs that viscosity is a very uncertain thing by which to judge the "whippability" of a mix.

E. S. Guthrie of Cornell presented a paper entitled "Body of Butter." His data covering a rather extensive period of observation shows that while medium worked butter is slightly superior to thoroughly worked goods in flavor (0.26 pt.), body (0.01 pt.) and hardness (0.41 pt. by the Perkins test), the advantage was all in favor of the thoroughly worked product since the composition was much more uniform and the shrinkage 28 pounds less per 1000 pounds than for the medium worked lots.

The next subject, "Uniformity of Methods of Manufacture of Cottage Cheese," was ably discussed by Carl E. Lee of the Gridley Dairy Company of Milwaukee in the short time at his disposal.

The demands for cottage cheese are so different as regards texture, firmness, acidity, etc., that no definite procedure can be given to suit

all purposes. In a general way the rapidity of cooking and temperature reached determines the type of curd. The Gridley Dairy Co. has been using a light cream to mix with the curd for retail cottage cheese putting the product into glass jars handled in the regular pint milk crate. For wholesale purposes to the restaurant, hotel and baker trade etc. a single service container similar to a lard can is used and the curd is in most cases packed raw.

The time being late other topics on the program were dispensed with.

Two papers covering topics on the program were received by the secretary. J. M. Sherman, Cornell, reported on the "Preservation of Cottage and Cream Cheeses in Vacuo."

Cream and cottage cheese after storage for one year at temperatures under 50°F. in vacuum sealed jars was still palatable. This method of packaging prevents mold and even at room temperatures extends the keeping period very pronouncedly. Machinery for packing in this fashion is not materially greater in cost than present machines and the cost of operation only slightly greater.

A. C. Dahlberg, Geneva, prepared a paper covering some work in progress at the Geneva Station on cream cheese. (See page 106, this issue.)

The resolution committee presented an appropriate resolution concerning the death of Professor W. A. Stocking, Jr., late of Cornell. This was ordered presented to the general session.

E. S. Guthrie, Ithaca, New York, was selected chairman and W. H. E. Reid, Columbia, Missouri was elected secretary.

Meeting adjourned at 6:00 p.m.

F. J. DOAN, *Acting Secretary.*

DAIRY EXTENSION SECTION

The Extension Section, of the American Dairy Science Association held its annual meeting at 2 p.m. Friday, October the 8th at the Book-Cadillac Hotel, Detroit. The meeting was in charge of A. J. Cramer, Chairman, Madison,. Wis., A. C. Balzer, Vice-Chairman, East Lansing, Michigan, and C. R. Gearhart, Secretary,

State College, Pa. A brief summary of reports from the five various committees follows:

1. The report of the Milk Campaign Committee was presented by Professor W. P. B. Lockwood for Miss Jessie Hoover of the Bureau of Dairying, Washington, D. C.

Milk campaigns have been successfully introduced in several states of the Union. Arkansas and Montana are two of the latest states to try this. In Hot Springs, Arkansas the consumption of milk per capita was one-fourth pint of milk daily before the campaign started. The daily consumption was just doubled in nine months. The home demonstration agent discovered that an increase of from 5 to 16 per cent in the weight of children was made in a period of 7 weeks after the amount of milk in the diet was doubled. Among the other states doing county wide campaigns are Washington and Wisconsin. The results of all milk campaign work, both rural and urban, have been highly satisfactory and it is known that the increased consumption of milk has greatly improved the health of the children in addition to the weight they have gained from it.

2. The report of the Committee on Feeding was made by C. A. Hutton of Tennessee.

The Dairy Extension men find it a big problem to get dairymen to adopt better feeding practices. And the committee men all found that the most effective way to get farmers to change their methods in feeding is through a Cow Testing Association. Next in favor after this method the feeding schools and barn meetings were found most effective. Many farmers will more readily ask questions and show more interest on the feeding subject if feeding is discussed in the barn rather than at formal meetings. It is thought that the briefly outlined feeding leaflets, circular letters and news letters, and bulletins are more effective than larger bulletins.

3. The Cow Testing Association Committee report was made by Mr. A. C. Baltzer of Michigan.

Now all states are living up to the use of Standard Uniform Cow Testing Association Rules, which were presented by the committee a year ago, receiving the approval of the American Dairy Science Association. It is recommended that the established Cow Testing Association rules

be continued. In many states the C. T. A. work has increased with the additional help of more dairy specialists in the field. The results of the work have shown a marked increase in profitable 300-pound butterfat herds. The committee for next year will work on the various methods employed in training of testers, getting publicity to the Cow Testing Association members and other dairymen and on the testers conferences. The committee presented a resolution for adoption by the Extension Section, to go to the Committee on Extension Organization and Policy of Land Grant Colleges to ask the U. S. D. A. to call a national meeting in Washington, D. C., of all Dairy Extension Specialists early in the spring of 1927 to get acquainted with the other workers of Extension to learn their problems and get the results of better methods for carrying on of our own work.

4. The report of Bull Associations Committee which is now called "Better Sires" Committee was made by Stanley Brownell of Pennsylvania for Mr. Geo. Gurbach of Michigan.

It was recommended that the terms "Grade Cow," "Proven Sire," and "Bull Association" be defined by a committee. There should be a coördination of the Better Sire work with other states. Now, every state works independent of other states. The committee recommends the Extension Section of the American Dairy Science Association request that the Bureau of Dairy Industry, U. S. D. A. assist by furnishing the necessary field force to coördinate "Better Sires" work between states. They also ask that the A. D. S. A. request the Bureau of Dairy Industry to use their influence to get data on the number and percentages of purebred sires of the dairy breeds by counties in the various states. It was suggested that the registered sires go free from taxation while the grade and scrub sires should be taxed to the limit. A workable plan for the certification of sires of proven merit may be formulated during the next year.

5. The Calf Club Committee report was made by Nevels Pearson of Michigan for T. A. Erickson of Minnesota.

The committee recommends that the club members' individual records and stories be considered in making awards at fairs. The personal effort made by the boy or girl should count in making awards. Most states have their club work on a three year basis. This should encourage the boy or girl to take a permanent interest in the work. Further sup-

port is needed to encourage dairy stock judging contests, showmanship, selection of calves and better methods of growing out of calves. The Committee recommends the selection of more heifer calves because often the bull becomes unruly and hard for the child to manage after the first year. The aim of the committee is to develop breeders of good purebred stock. The committee is asking for assistance to curb the high abnormal prices asked for calves for calf club work. We need the purebred breeders coöperation if the boys and girls are to become successful breeders of good dairy stock.

6. The Dairy Manufacturers Committee did not send a representative or hand in a report.

A motion was passed to the effect that the Program Committee arrange that the Production and Extension Sections do not hold their meetings at the same hours.

The Nomination Committee re-appointed the officers of this year to serve for the coming year, namely:

A. J. Cramer, Chairman, Madison, Wisconsin.
A. C. Baltzer, Vice Chairman, East Lansing, Michigan.
C. R. Gearhart, Secretary, State College, Pennsylvania.

(Signed) C. R. GEARHART, *Secretary*.

OFFICIAL TESTING SECTION

The meeting of Section IV, Official Testing Section of the American Dairy Science Association was held Thursday, October 7, 1926, at the Book-Cadillac Hotel, Detroit, Michigan.

Meeting was called to order by Chairman C. E. Wylie.

Minutes of previous meeting were read by secretary W. E. Peterson and approved. Mr. M. H. Campbell, chairman of the Breeds Relation Committee read report for that committee. Report was accepted. The most important phases of this report are:

1. Addition to official test rules that supervisor and milker refrain from talking during milking.

2. Addition to official test rules that "The supervisor shall run a blank test on all the sulphuric acid, consisting of 17.6 cc. acid and sufficient water to fill the bottle."

3. A resolution to all breed associations requesting them that the revised rules of the American Dairy Science Association, governing official testing be published in the different breed association handbooks.

Mr. C. T. Conklin, secretary of the Ayrshire Breeders' Association reported on the Ayrshire Herd Test Plan. He reported general satisfaction with the present plan and that it had greatly stimulated interest in testing.

Mr. P. S. Williams of Pennsylvania presented a paper on supervising the Herd Test Plan.

Dr. C. H. Eckles of Minnesota presented a paper on The History and Trend of Official Testing.

Mr. R. T. Harris, of Wisconsin, chairman of the Investigations Committee, reported for that committee. The report was adopted as read.

Little work has been undertaken by this committee during the past year.

Darnell of the Texas station reports work still in progress in a study involving the effects of feeding cottonseed meal to dairy cows on official test. More facilities are to be available another year so this study may be continued on a larger scale and valuable results are anticipated.

Petersen of the Minnesota station reports further on the possibility of adulterating ordinary commercial sulphuric acid so as to increase the reading of the Babcock test in which such acid is used. He has been able to secure an acid emulsion that is stable and that will increase the Babcock reading when used in making the test. An increased reading as high as 0.8 per cent is noted. The emulsion is stable and the appearance and action of the treated acid normal. As indicated last year such adulteration can be easily detected by running blank tests using water instead of milk and completing the test in the usual manner.

Harris of the Wisconsin station reports on a trial to determine the practical application of a herd test plan adaptable to all breeds and reduced to the simplest possible terms. After eighteen months he finds that (*a*) records made are reliable, (*b*) some low producers are eliminated, (*c*) good sires located, (*d*) members well satisfied with results and (*e*) test supervisors interested and regard plan with favor. The plan, known locally as the Herd Improvement Record, is based upon the standard

cow testing association methods and provides for retests, inspections, checking for accuracy and permanent filing of records. Certificates are issued to herds with average above 300 pounds butterfat in the year, but none to individual cows. Offered as a supplement rather than a substitute for A. R. work. To date about 50 herds entered with 1000 cows, including Brown Swiss, Guernsey, Holstein and Jersey breeders.

Breed representatives were called on for remarks. Lynn Copeland responded for the American Jersey Cattle Club, reporting a marked increase in testing after the adoption of the one-day test.

Mr. Harris of Wisconsin reported for Mr. Gardner of the Holstein Friesian Association that the one-day test has been made optional to breeders doing Class C testing.

Mr. P. S. Williams, State College Pa., and Mr. J. M. Fuller, Durham, N. H., were elected president and secretary respectively.

Meeting adjourned.

WILLIAM E. PETERSEN, *Secretary.*

OFFICERS OF AMERICAN DAIRY SCIENCE ASSOCIATION, 1927

The mail ballot taken in December, 1926, resulted in the election of the following officers:

President: J. B. Fitch, Manhattan, Kansas

Vice-President: J. M. Sherman, Ithaca, New York

Officers of Eastern Division, A. D. S. A.: Chairman, J. M. Fuller, Durham, New Hampshire; Secretary, S. H. Harvey, College Park, Maryland.

Officers of Western Division: Chairman, F. W. Atkeson, Moscow, Idaho; Secretary, N. C. Jamison, Corvallis, Oregon.

Officers of Southern Division: Chairman, J. S. Moore, Agricultural College, Mississippi; Secretary, A. C. Baer, Stillwater, Oklahoma.

Summer Meeting of the American Dairy Science Association

In accordance with the resolution passed at the last meeting of the Dairy Science Association, the Executive Committee has voted to hold a summer meeting at the Agricultural College, East Lansing, Michigan, June 22, 23, 24, 1927.

The tentative plans for the arrangement of the program are as follows:

First Day

10:30 to 12:00
1:30 to 4:00 Instruction in Dairy Husbandry
Program will consist of limited number of papers with ample time for discussion.

Second Day

9:30 to 12:00
1:30 to 4:00 Research Program
Program will consist of a series of short papers (limit 10 minutes), each followed by a short discussion period.

Third Day

9:30 to 12:00 Extension Methods and Results
1:30 to 4:00 Section 1, Dairy Manufacturers
Joint meeting Section 1, Production; and Section 3, Extension.
Program to include subjects of special interest to sections and any matters of business needing attention.

No programs will be scheduled for the evenings, leaving opportunity for special conferences, social and recreational activities.

The success of the proposed program depends upon the response of the membership. The committee asks every member of the

association and especially those having administrative charge of dairy departments of colleges to give the matter of program prompt attention. Suggestions are invited regarding the program in general. Members desiring to present papers are requested to send title and author at once. Papers presented on Research Program may be in the nature of an abstract of a paper to be presented for publication later, or may be a report of work in progress or completed and not intended for publication; or a discussion of plans and methods of research.

PROGRAM COMMITTEE

C. C. HAYDEN,
Experiment Station, Wooster, Ohio.
H. A. RUEHE,
University of Illinois, Urbana, Ill.
C. H. ECKLES, CHAIRMAN
University Farm, St. Paul, Minn.

BOOK REVIEW

Professor Victor Arthur Rice of the Animal and Dairy Husbandry Department, Massachusetts Agricultural College is the author of a new text book BREEDING AND IMPROVEMENT OF FARM ANIMALS, published by McGraw Hill Book Company, New York.

This book covers in a thoroughly scientific and yet practical manner such subjects as physical basis of inheritance, sterility, reproductive efficiency, genetics, acquired characters, sex determination, grading and cross breeding, inbreeding, selection of farm animals and fitting for sale. It has been written primarily as a text book for students in animal breeding but is also a valuable reference book for the practical livestock man.

J. H. F.

HISTORY OF DAIRYING, a history of the dairy industry representing over 15 years of research by the author, T. R. Pirtle, is now off the press. The volume contains 645 pages, 203 illustrations, and graphs, and covers the subject in all countries of the world.

An interesting feature of the book is the International Chronological Index of Events dated from 4000 B.C. when cattle and dairying were found in Switzerland, through 1000 A.D. with the first record of ground cheese, supposed to be a new process.

This index contains the main steps in the industry including the first cooperative cheese making, in 1380 in the Balkans; record of foot and mouth disease in 1700 in France. Pasteurization of milk discovered in 1857–1862, in France. The thermometer was first used in dairy work in 1870 in Denmark; the cream separator invented in 1878 in Sweden. Butter fat testers were made by Dr. Gerber in Switzerland and by Dr. Babcock in the United States in 1888 and in 1890, respectively.

The work is designed to be of interest as a text book for students and as a reference to leaders in the industry.

The book is published by Mojonnier Brothers Company, Chicago.

J. H. F.

INTERNATIONAL DAIRY EXHIBIT

An International exhibition of dairy machinery will be held in Berlin, Germany, August 16–20, 1927 in connection with the thirty-sixth meeting of the Association of German Dairy Scientists. Information regarding the prizes offered can be secured from Paul Funke, Chausseestrasse 8, Berlin N. 4, Germany.

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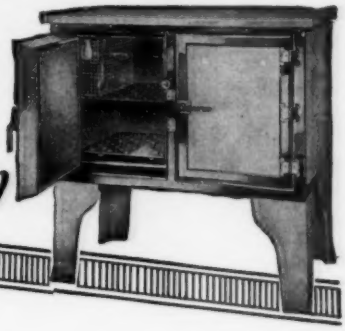

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